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Ms. Jacquelyn Hayes
Remedial Project Manager
U.S. Environmental Protection Agency - Region 9
75 Hawthorne Street, SFD-8-2
San Francisco, CA 94105

Subject: **Revised Data Summary Report for the Characterization of Potential Cover Materials, Yerington Mine Site, Lyon County, Nevada: Administrative Order on Consent, CERCLA Docket No. 09-2009-0010**

Dear Ms. Hayes:

Atlantic Richfield Company (ARC) has prepared this revised *Data Summary Report for the Characterization of Potential Cover Materials, Yerington Mine Site* (Cover Materials DSR - Revision 1) dated June 10, 2011 pursuant to: 1) the *Cover Materials Characterization Work Plan - Revision 2* (Revised Work Plan; Brown and Caldwell, 2010a) for the Yerington Mine Site (Site) dated November 17, 2010, which was approved by EPA on November 12, 2010; and 2) comments provided by the U.S. Environmental Protection Agency - Region 9 (EPA) and the Yerington Paiute Tribe on the March 18, 2011 submittal of the Cover Materials DSR (comments were transmitted on May 27, 2011). EPA requested the investigation of potential cover materials in the March 18, 2010 e-mail correspondence to ARC entitled "Anaconda Evaporation Ponds Removal Actions". The March 18, 2010 e-mail correspondence refers to removal actions required by the subject Administrative Order on Consent (AOC) and attached Scope of Work[1] (SOW), dated April 21, 2009.

Data presented in this Cover Materials DSR - Revision 1 will also support remedial investigations and feasibility studies for several operable units (OUs) at the Site, pursuant to the Administrative Order for Remedial Investigation and Feasibility Study (RI/FS; CERCLA Docket No. 9-2007-0005) dated January 12, 2007 (2007 Order). The location of the Site is shown on Figure 1, and the locations of Site OUs, as identified by EPA in the 2007 Order, are shown on Figure 2 (Site-wide groundwater not shown):

- Site-wide Groundwater (OU-1);
- Pit Lake (OU-2);
- Process Areas (OU-3);
- Evaporation Ponds and Sulfide Tailings (OU-4);
- Waste Rock Areas (OU-5);
- Oxide Tailings Areas (OU-6);
- Wabuska Drain (OU-7); and
- Arimetco Facilities (OU-8 - EPA responsibility).

This Potential Cover Materials DSR includes the following sections, tables, figures and attachments:

[1] Administrative Order on Consent and Settlement Agreement for Past Response Costs Anaconda Copper Mine, Yerington Nevada; U.S. EPA Region IX; CERCLA Docket No. 09-2009-0010.

Sections

Tables

Figures

Attachments (Compact Disc)

Attachment 1	Field Log Books and Photographs/MWMP Methods
Attachment 2	BC and ESI Technical Memoranda
Attachment 3	Total Metals and Radiochemicals Data
Attachment 4	Meteoric Water Mobility Procedure Data
Attachment 5	Acid-Base Accounting Data
Attachment 6	Plant Growth Parameter Data
Attachment 7	Geotechnical Report
Attachment 8	Pre-Existing Arimetco Heap Leach Pad Data

Tables embedded in the text are included for the results described in the acid generation potential and plant growth parameter sections. Summary data tables and graphics for total metals and radiochemicals, MWMP results and geotechnical/hydraulic testing are only presented in Attachments 3, 4 and 7, respectively. A separate section describing rock grab sample analytical results (total metals and radiochemicals, MWMP leachate, and potential acid generation results) from waste rock areas (WRAs) has been included for these samples due to their specific potential use (i.e., capillary break materials) in interim cover or final cap designs, as described in the Revised Work Plan. The analytical data and associated information for these rock grab samples are provided in Attachments 3 through 5.

Attachment 7 provides the geotechnical report prepared by Applied Soil Water Technologies LLC (ASWT), located in Sparks, Nevada. This report describes the analyses of, and results for, geotechnical and hydraulic properties of potential cover materials. The ASWT report includes its own set of attachments (A through L). Attachment 8 includes pre-existing Arimetco Heap Leach Pad (HLP) data collected by CH2M Hill on behalf of EPA (CH2M Hill, 2008).

Characterization Objectives

The data presented in this Potential Cover Materials DSR are intended to support decisions regarding materials that may be used for interim covers and/or the design of final closure caps, and supplement pre-existing data previously collected by ARC, EPA and the Nevada Division of Environmental Protection (NDEP). Pre-existing data and the data resulting from the implementation of the Revised Work Plan include geochemical data, plant growth parameters and geotechnical/hydraulic properties. Results presented herein will also improve the conceptual model of potential on- and off-Site cover materials. Interim covers and/or final closure caps may be required for the following Site OUs (Figure 2):

- Process Areas (OU-3);
- Evaporation Ponds and Sulfide Tailings (OU-4);
- Waste Rock Areas (OU-5);
- Oxide Tailings Areas (OU-6); and
- Arimetco Facilities (OU-8).

Summary of Field Activities

On-Site samples were obtained from the following OUs: OU-4, OU-5, OU-6 and OU-8. Off-Site native alluvium samples were collected from the alluvial fan located west of the Site. Potential cover material samples were collected between September 28 and October 7, 2010, at the locations shown on Figures 3 through 7, using a backhoe hand auger and surface grab sampling, depending on the nature of the materials and heavy equipment access to the sample locations. The majority of samples were collected from excavations to depths of up to 5 feet below ground surface (bgs) using a rubber-tire backhoe (three sulfide tailings samples were collected up to 8 feet bgs). A summary of the samples collected and the associated geochemical and geotechnical analyses for each location and sample interval is presented in Table 1. Field log books and photographs of sample locations are provided in Attachment 1.

Sample Collection Methods

Sampling activities were performed by the Brown and Caldwell sampler in accordance with the Revised Work Plan and the updated *Quality Assurance Project Plan - Revision 5* (QAPP; ESI and Brown and Caldwell, 2009), and associated standard operating procedures (SOPs). Approximately two thirds of the samples were collected by backhoe excavations from 2 to 8 feet deep (see below), depending on the location and field conditions. All sample collection activities were subject to EPA oversight. Technical memoranda responding to comments provided by EPA's contractor related to potential SOP deviations are discussed below, and provided in Attachment 2.

Samples collected from backhoe excavations represent a composite of excavated materials from the backhoe bucket piles that include all depth intervals within the excavation. Backhoe sampling methods consisted of: 1) positioning the backhoe at the planned sample location; 2) excavating the sample to the desired depth; 3) laying out the excavated materials in sequential piles adjacent to the excavation so that all depths were accessible for visual inspection and selection of appropriate materials to be consolidated into the sample; and 4) using a shovel to collect representative material from all of the backhoe piles and placing the materials in clean, new 5-gallon buckets for screening (as required), blending, and distribution to the laboratory sample containers.

Sample collection from the backhoe excavations was performed using the best professional judgment of the sampler to provide appropriate samples with respect to the grain-size requirements of the laboratory analyses described below. Materials were selected from excavated piles rather than from the walls of the excavation to: 1) ensure that representative samples (e.g., coarse- and fine-grained material types from all horizons) were collected; and 2) avoid entering a potentially unstable 5-foot deep trench, pursuant to the *Site Health and Safety Plan - Revision 1* (HASP; Brown and Caldwell, 2009a).

Seven of the ten samples of vat leach tailings (VLT) from the Oxide Tailings Area (OU-6) were collected by hand auger due to the inability of the backhoe to access these locations for safety reasons. VLT materials from the auger bucket were placed in clean 5-gallon buckets and blended for distribution to sample containers and the auger was decontaminated between sample locations using the procedures outlined below. Rock samples (nominal 2-inch plus size) collected from the WRAs (OU-5) were judgmentally selected by the sampler to represent weak or no mineralization, moderate mineralization, and strong mineralization. Rock samples were collected by gloved hand and placed in a ziplock bag and bucket. As needed, a rock hammer was used to break larger rocks to a manageable sample size.

Samples were prepared in the field for submittal to the various analytical labs pursuant to the analyses described in the Revised Work Plan, as follows (please refer to Table 1):

- *Plant Growth Parameters* - Materials were collected from excavation piles using a clean, decontaminated painted steel garden shovel. The soil was placed on a clean, decontaminated 2-mesh screen (opening size of 7/16 inches) situated over a new 5-gallon bucket. The sieved materials were blended using a clean, decontaminated plastic garden trowel and scooped into a 1-quart plastic ziplock bag for submittal to the A&L Western lab in Modesto, California.

- *Total Metals and Radiochemicals* **-** One-gallon ziplock bags were filled from the screened and blended materials used to create the plant growth parameter samples. In addition, several handfuls of the screened coarser-grained materials (i.e., rocks) were added back into the sample bags to represent the excavated materials. The sample bags were then submitted to the TestAmerica Richland lab for sample preparation (crushing and drying). The prepped materials were then distributed to the TestAmerica Irvine lab for metals analysis. Sample bags were placed inside a chilled cooler upon collection and then placed in a refrigerator for storage until shipment. Samples were shipped on ice for next-day delivery.

- *MWMP and ABA* - A commercially available plastic garbage bag was placed inside a new clean 5-gallon bucket and the bucket was filled by taking representative aliquots from each of the excavation piles or auger samples. Materials placed in the buckets were not field screened using the 2-mesh screen. The bucket was typically filled up to three-quarters full, the interior liner was twisted and taped shut, and the bucket lid was put on and a taped seal was put around the entire bucket lid. Buckets were hand delivered to Sierra Environmental Monitoring (SEM) in Reno, Nevada.

- SEM prepared the MWMP leachate for each sample in accordance with ASTM E2242 and the methods provided in Attachment 1. The water used for the MWMP conformed to Type II specifications (i.e., purified laboratory reagent water with no buffering capacity). The MWMP leachate was returned to Brown and Caldwell, and was then submitted to the appropriate TestAmerica lab for metals and radiochemical analysis.

- *Geotechnical/Hydraulic Properties* - Bulk samples were collected as described above by filling two lined 5-gallon buckets. Although the materials were not screened, rocks greater than 3 inches in size were intentionally excluded. The liner and bucket were sealed and were hand delivered to Applied Soil Water Technologies (ASWT) in Sparks, Nevada.

<u>Collected Sample Analytical Parameters</u>
Samples were collected for some or all of the following analyses (refer to Table 1):

- Total metals and radiochemicals (radium-226/228)
- Meteoric Water Mobility Leaching Procedure (MWMP) analyzed for metals and radiochemicals
- Acid Base Accounting (ABA) and Net Acid Generation (NAG)
- Plant growth parameters
- Geotechnical/geohydraulic parameters

Pursuant to the Revised Work Plan, the following borrow source areas for potential cover materials were sampled (refer to Figures 3 through 7 and Table 1):

- *Native Alluvium West of the Site:* Two reference sub-areas west of the Site, Sub-Area 1 and Sub-Area 2, were identified for the *Background Soils Data Summary Report -Revision 1* dated March 9, 2009 (Brown and Caldwell, 2009b). The Revised Work Plan identified five sample locations of native alluvium that were previously sampled for total metals and radiochemicals during the background soils investigation. Therefore, these samples of native alluvium were analyzed for all analytes except for total metals and radiochemicals.

  Samples of native alluvium samples were collected at the following background soil sample locations (Figure 7): CM-BGS-01 (co-located with background soil sample BGS-A1-15), CM-BGS-03, (BGS-A1-03) and CM-BGS-04 (BGS-A1-19); and samples CM-BGS-02 (BGS-A2-43) and CM-BGS-05 (BGS-A2-51). Sub-Areas A1 and A2 are included in each sample designation.

- *South Waste Rock Area:* Five locations sampled by backhoe included four alluvial soil stockpiles and one waste rock stockpile (CM-SWR-01 through -05; Figure 3), which were submitted for all analytical suites listed above. Four surface grab samples of waste rock were collected (CM-SWR-06 through -09), but were not submitted for geotechnical analysis or plant growth parameters because the coarse nature of this material is not suitable for these analyses.

- *W-3 Waste Rock Area:* Three locations (CM-WR3-01 through -03) were sampled by backhoe and submitted for the full analytical suite (these samples included coarse-grained materials). Four coarse rock grab samples (CM-WR3-04 through -07) were collected, and were not analyzed for geotechnical and plant growth parameters. Sample locations are shown on Figure 4.

- *S-23 Sulfide Waste Rock Area:* Three locations (CM-S23-01 through -03) were sampled by backhoe from this WRA (previously misidentified as S-32) for the full analytical suite listed list above, and four rock grab samples were submitted for the reduced list shown in Table-1.

- *Oxide Tailings:* VLT materials were sampled in 2010 as part of the *Revised VLT Characterization Work Plan Using X-Ray Fluorescence, Yerington Mine Site* (XRF Work Plan; Brown and Caldwell 2009c). The analytical results for these samples were summarized in the *XRF Data Summary Report* (Brown and Caldwell 2010b). VLT samples collected pursuant to the Revised Work Plan were intended to supplement these data, and were collected at the 10 locations shown on Figure 5, which were co-located with previously collected samples for total metals as part of the XRF evaluation. Therefore, none of the samples collected pursuant to this Revised Work Plan were analyzed for total metals. Three of the ten locations were sampled by backhoe (CM-VLT-05, -06 and -09; Figure 5) and were submitted for the full suite of analytes (minus total metals). The remaining locations were sampled by hand auger and were analyzed only for geochemical parameters (radiochemicals, MWMP, and ABA/NAG).

- *Arimetco Heap Leach Pads:* Two samples were collected on each of the five Arimetco HLPs (Figures 4 and 5). One of the two samples from each HLP was submitted for geotechnical analysis and plant growth parameters, and the second sample was submitted for only plant growth parameters. These samples were intended to supplement previous data collected by EPA (CH2M Hill, 2008).

- *Sulfide Tailings:* Three locations (CM-SUL-01 through -03; Figure 6) were sampled by backhoe and submitted for the full analytical suite (Table 1).

- *Quality Control Samples:* Three duplicate samples were collected and submitted for only metals, radiochemicals and plant growth parameters. Two equipment blank samples were collected on decontaminated reusable sampling equipment, and were analyzed for total metals.

The following sample locations (Figures 3 through 7) were modified from the locations presented in the Revised Work Plan (Figures 5-1 through 5-5) for the following reasons (all modifications were approved in the field by EPA's representative prior to sample collection):

South Waste Rock Area

- CM-SWR-01 was relocated approximately 300 feet north because the narrow bench was inaccessible to field vehicles.
- CM-SWR-04 was relocated approximately 500 feet west of the original location due to rough terrain causing inaccessibility for field vehicles.
- CM-SWR-05 was relocated approximately 600 feet northeast to a location that was accessible by field vehicles.
- CM-SWR-06 through CM-SWR-09 sample locations (rock grab samples) were judgmentally selected to meet the objectives of selecting various degrees of mineralization.

W-3 Waste Rock Area

- CM-WR3-02 was relocated approximately 500 feet south west to a lower bench that was accessible to field vehicles.
- CM-WR3-05 through CM-WR3-07 sample locations (rock grab samples) were judgmentally selected to meet the objectives of selecting various degrees of mineralization.

S-23 Waste Rock Area

- CM-S23-05 (rock grab samples) was judgmentally selected to meet the objectives of selecting various degrees of mineralization.

Oxide Tailings Area

- CM-VLT-01 and CM-VLT-02 were relocated to an upper bench ~600 and 400 ft east to locations that were accessible by field vehicles.

The maximum 5-foot depth for potential cover material samples was modified based on the following field conditions or lab requirements:

- Off-Site alluvial soil samples were collected to a total depth of 3 feet bgs to: 1) allow field personnel to enter the pit and examine in-situ soil horizons and material types in the excavation wall; and 2) be consistent with data presented in the *Background Soils Data Summary Report - Revision 1* dated March 9, 2009 (Brown and Caldwell, 2009b).
- Sulfide tailings samples were collected over a 5-foot interval below the VLT cap, which varies in thickness between 18 to 48 inches and resulted in sample depths up to 8 feet bgs (excavation depths varied between 6.5 and 8 feet deep).
- Samples from the Arimetco HLPs that were submitted for only plant growth parameter analyses were limited to a depth of 3 feet bgs as this is the typical sample interval for agricultural tests (i.e., the zone where plant growth rooting would typically occur).
- Hand-augered VLT samples were collected to a depth of 4 feet bgs (the limit of the hand auger).

<u>Field Decontamination Procedures</u>

All reusable field sampling equipment, with the exception of the backhoe bucket, were subject to the following decontamination procedure:

1) Wash with non-phosphate soap (Liquinox) in a 5-gallon bucket of tap water and scrubbed with a plastic scrub brush.
2) Rinse in a 5-gallon bucket of tap water from the Site water supply in the Lab.
3) A final rinse with distilled water sprayed from a pressure spray tank onto the cleaned equipment.
4) Cleaned equipment was either allowed to air dry or was wiped dry using a heavy-duty disposable shop towel.

Reusable equipment used to collect cover material samples included:

1) A steel garden shovel (purchased new for this project).
2) A small plastic hand-held garden trowel (purchased new).
3) A 12-inch diameter 2-mesh screen with plastic rim exterior and steel metal screen wires (purchased new).

Single-use equipment used to collect samples not subject to decontamination procedures included:

1) Disposable nitrile gloves
2) Plastic ziplock bags
3) Consumer grade plastic trash bags
4) Plastic 5-gallon buckets

A nitric acid rinse was not used to decontaminate field equipment because the *ASTM Standard Practices for Decontamination of Field Equipment Used at Waste Site (ASTM D 5088-02)* states that a nitric acid rinse is not effective for metal and stainless steel sampling tools. This would apply to the shovel and screen, but not to the plastic scoop. Although the nitric acid rinse step (described in SOP-5) on the plastic scoop may have effectively removed inorganic contaminants from the scoop not removed by the steps listed above, a field judgment was made to not use the nitric acid rinse step on the plastic scoop because it was not used on the shovel or screen. Two rinsate blanks for the plastic scoop were collected from the 26 samples (more than the five percent required by the QAPP) to determine if the decontamination steps listed above for this piece of equipment were effective. A technical memorandum and related information submitted to EPA on November 24, 2010 that describes this situation is provided in Attachment 2 of this Potential Cover Materials DSR. During project data validation, Environmental Standards, Inc. (ESI) evaluated the rinsate blank sample results and prepared a memorandum describing the reasoning used to determine that the soil samples were not affected by the modified decontamination procedure. A copy of the memorandum prepared by ESI is provided in Attachment 2.

Table 1. Sample Collection Summary

Sample ID	Location	Date Sampled	Sample Description					Analysis Requested					
			Material	Mineralization	Rock Type	Sample Method	Sample Depth	Total Metals	Radiochemicals	MWMP	Geotech/hydraulic analysis	ABA/NAG	Plant Growth Parameters
CM-BGS-01	Background (Native) Alluvium	9/28/2010	Alluvial soil	None		Backhoe	0 - 38"			x	x	x	x
CM-BGS-02	Background (Native) Alluvium	9/28/2010	Alluvial soil	None		Backhoe	0 - 36"			x	x	x	x
CM-BGS-03	Background (Native) Alluvium	9/28/2010	Alluvial soil	None		Backhoe	0 - 36"			x	x	x	x
CM-BGS-04	Background (Native) Alluvium	9/28/2010	Alluvial soil	None		Backhoe	0 - 34"			x	x	x	x
CM-BGS-05	Background (Native) Alluvium	9/28/2010	Alluvial soil	None		Backhoe	0 - 42"			x	x	x	x
CM-SWR-01	South Waste Rock Area	9/29/2010	Alluvial soil	None		Backhoe	0 - 60"	x	x	x	x	x	x
CM-SWR-02	South Waste Rock Area	9/29/2010	Alluvial soil	None		Backhoe	0 - 60"	x	x	x	x	x	x
CM-SWR-03	South Waste Rock Area	9/29/2010	Alluvial soil	None		Backhoe	0 - 60"	x	x	x	x	x	x
CM-SWR-04	South Waste Rock Area	9/29/2010	Alluvial soil	None		Backhoe	0 - 62"	x	x	x	x	x	x
CM-SWR-05	South Waste Rock Area	9/29/2010	Unsorted rock	Undetermined		Backhoe	0 - 56"	x	x	x	x	x	x
CM-SWR-06	South Waste Rock Area	10/1/2010	Coarse rock	None-Weak	Monzonite	Surface grab	0"	x	x	x		x	
CM-SWR-07	South Waste Rock Area	10/1/2010	Coarse rock	Mod	Granodiorite	Surface grab	0"	x	x	x		x	
CM-SWR-08	South Waste Rock Area	10/1/2010	Coarse rock	Mod	Monzonite	Surface grab	0"	x	x	x		x	
CM-SWR-09	South Waste Rock Area	10/1/2010	Coarse rock	Mod-Strong	Monzonite	Surface grab	0"	x	x	x		x	
CM-WR3-01	WR-3 Waste Rock Area	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 72"	x	x	x	x	x	x
CM-WR3-02	WR-3 Waste Rock Area	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 60"	x	x	x	x	x	x
CM-WR3-03	WR-3 Waste Rock Area	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 60"	x	x	x	x	x	x
CM-WR3-04	WR-3 Waste Rock Area	10/7/2010	Coarse rock	Weak	Monzonite	Surface grab	0"	x	x	x		x	
CM-WR3-05	WR-3 Waste Rock Area	10/7/2010	Coarse rock	Mod-Strong	Granite	Surface grab	0"	x	x	x		x	
CM-WR3-06	WR-3 Waste Rock Area	10/7/2010	Coarse rock	Weak	Monzonite	Surface grab	0"	x	x	x		x	
CM-WR3-07	WR-3 Waste Rock Area	10/7/2010	Coarse rock	Mod	Monzonite	Surface grab	0"	x	x	x		x	
CM-S23-01	Sulfide (S-23) Waste Rock Area	9/29/2010	Unsorted rock	Undetermined		Backhoe	0 - 60"	x	x	x	x	x	x
CM-S23-02	Sulfide (S-23) Waste Rock Area	9/29/2010	Unsorted rock	Undetermined		Backhoe	0 - 60"	x	x	x	x	x	x

Table 1. Sample Collection Summary

Sample ID	Location	Date Sampled	Sample Description					Analysis Requested					
			Material	Mineralization	Rock Type	Sample Method	Sample Depth	Total Metals	Radiochemicals	MWMP	Geotech/hydraulic analysis	ABA/NAG	Plant Growth Parameters
CM-S23-03	Sulfide (S-23) Waste Rock Area	9/29/2010	Unsorted rock	Undetermined		Backhoe	0 - 63"	x	x	x	x	x	x
CM-S23-04	Sulfide (S-23) Waste Rock Area	9/28/2010	Coarse rock	Mod	Granodiorite	Surface grab	0"	x	x	x		x	
CM-S23-05	Sulfide (S-23) Waste Rock Area	10/7/2010	Coarse rock	Mod-Strong	Granodiorite	Surface grab	0"	x	x	x		x	
CM-S23-06	Sulfide (S-23) Waste Rock Area	10/7/2010	Coarse rock	Weak	Monzonite	Surface grab	0"	x	x	x		x	
CM-S23-07	Sulfide (S-23) Waste Rock Area	10/7/2010	Coarse rock	Strong	mafic vein	Surface grab	0"	x	x	x		x	
CM-SUL-01	Sulfide Tailings	10/1/2010	Sand/clay tailings	Undetermined		Backhoe	48 - 96"	x	x	x	x	x	x
CM-SUL-02	Sulfide Tailings	10/1/2010	Sand/clay tailings	Undetermined		Backhoe	18 - 79"	x	x	x	x	x	x
CM-SUL-03	Sulfide Tailings	10/1/2010	Sand/clay tailings	Undetermined		Backhoe	18 - 84"	x	x	x	x	x	x
CM-VLT-01	Oxide Tailings	10/6/2010	Crushed rock	Undetermined		Hand auger	0 - 48"		x	x		x	
CM-VLT-02	Oxide Tailings	10/6/2010	Crushed rock	Undetermined		Hand auger	0 - 12"		x	x		x	
CM-VLT-03	Oxide Tailings	10/6/2010	Crushed rock	Undetermined		Hand auger	0 - 48"		x	x		x	
CM-VLT-04	Oxide Tailings	10/6/2010	Crushed rock	Undetermined		Hand auger	0 - 48"		x	x		x	
CM-VLT-05	Oxide Tailings	10/1/2010	Crushed rock	Undetermined		Backhoe	0 - 64"		x	x	x	x	x
CM-VLT-06	Oxide Tailings	10/1/2010	Crushed rock	Undetermined		Backhoe	0 - 67"		x	x	x	x	x
CM-VLT-07	Oxide Tailings	10/6/2010	Crushed rock	Undetermined		Hand auger	0 - 48"		x	x		x	
CM-VLT-08	Oxide Tailings	10/6/2010	Crushed rock	Undetermined		Hand auger	0 - 48"		x	x		x	
CM-VLT-09	Oxide Tailings	10/1/2010	Crushed rock	Undetermined		Backhoe	0 - 67"		x	x	x	x	x
CM-VLT-10	Oxide Tailings	10/6/2010	Crushed rock	Undetermined		Hand auger	0 - 48"		x	x		x	
CM-HLP-01	Arimetco HLP (Phase IV Slot)	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 63"				x		x
CM-HLP-02	Arimetco HLP (Phase IV Slot)	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 29"						x
CM-HLP-03	Arimetco HLP (Phase II)	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 60"				x		x
CM-HLP-04	Arimetco HLP (Phase II)	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 24"						x
CM-HLP-05	Arimetco HLP (Phase III South)	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 60"				x		x
CM-HLP-06	Arimetco HLP (Phase III South)	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 18"						x

Table 1. Sample Collection Summary

			Sample Description					Analysis Requested					
Sample ID	Location	Date Sampled	Material	Mineralization	Rock Type	Sample Method	Sample Depth	Total Metals	Radiochemicals	MWMP	Geotech/hydraulic analysis	ABA/NAG	Plant Growth Parameters
CM-HLP-07	Arimetco HLP (Phase III 4X)	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 60"				x		x
CM-HLP-08	Arimetco HLP (Phase III 4X)	9/30/2010	Unsorted rock	Undetermined		Backhoe	0 - 20"						x
CM-HLP-09	Arimetco HLP (Phase IV VLT)	10/1/2010	Unsorted rock	Undetermined		Backhoe	0 - 72"				x		x
CM-HLP-10	Arimetco HLP (Phase IV VLT)	10/1/2010	Unsorted rock	Undetermined		Backhoe	0 - 24"						x
QC Samples													
Dup-1	CM-SWR-03	9/29/2010	Soil			Backhoe		x	x				x
Dup-2	CM-S23-01	9/29/2010	Soil			Backhoe		x	x				x
Dup-3	CM-WR3-03	9/30/2010	Soil			Backhoe		x	x				x
EB-01	Equipment blank	9/29/2010	Water			Grab		x					
EB-02	Equipment blank	9/30/2010	Water			Grab		x					

Analytical Results for Total Metals and Radiochemicals

Potential cover materials were analyzed for their concentrations of 27 total metals, including thorium and uranium, and for radium-226/-228 isotopes. Analytical results, laboratory reports, summary statistic tables, and charts of mean concentration for total metals and radiochemicals are provided in Attachment 3. As indicated above, ARC characterized background soils from two off-Site native alluvium reference areas (148 samples from Sub-Areas A1 and A2).

The background soils data and associated background concentration limits (Brown and Caldwell, 2009b), which have been supplemented by the Native Alluvium data described below, provide a baseline reference for the following discussion of metal and radiochemical concentrations. These background concentration limits (BCLs), and EPA Regional Screening Levels (RSLs; EPA, 2010), for Industrial Soil, are summarized in Table 2. Analytical results for total metals and radiochemicals for rock grab samples from the waste rock areas are presented are presented at the end of this section.

<u>Aluminum</u>
Aluminum was detected in all samples in all potential cover materials. The minimum aluminum concentration of 3100 milligrams per kilogram (mg/kg) was from the S-23 WRA and the maximum of 28,000 mg/kg was from the Native Alluvium. The mean aluminum concentration in Native Alluvium was 9,469 mg/kg, which was above the mean concentrations of all on-Site potential cover materials. The next highest mean was the South WRA at 9,200 mg/kg. The BCL for aluminum is 25,436 mg/kg and the RSL is 990,000 mg/kg.

<u>Antimony</u>
Antimony was not detected in any Native Alluvium samples, but was detected at a frequency range of 42 to 100 percent in on-Site cover material samples. The minimum antimony concentration of 0.25 mg/kg was from the Arimetco HLPs and the maximum of 20 mg/kg was from the W-3 WRA. The W-3 WRA had the highest mean antimony concentration at 8.9 mg/kg while the other on-Site potential cover materials had a significantly lower mean concentration range of 0.60 to 2.4 mg/kg. The BCL for antimony is 1.8 mg/kg and the RSL for metallic antimony is 41 mg/kg.

<u>Arsenic</u>
Arsenic was detected in 90 percent of Native Alluvium samples, and nearly 100 percent in on-Site cover material samples. The minimum arsenic concentration of 1.7 mg/kg and the maximum of 31.6 mg/kg were both from the Arimetco HLPs. The mean arsenic concentration in Native Alluvium was 5.2 mg/kg, which was mid-range for the mean concentrations of on-Site potential cover materials. Samples from the Arimetco HLPs had the highest mean value (10 mg/kg), and the Sulfide Tailings had the lowest mean value (3.2 mg/kg). The BCL for arsenic is 17 mg/kg and the RSL for inorganic arsenic is 1.6 mg/kg.

<u>Barium</u>
Barium was detected in all but two samples in all potential cover materials. The minimum barium concentration of 20 mg/kg and the maximum of 620 mg/kg were both from the W-3 WRA. The mean barium concentration in Native Alluvium was 98 mg/kg. The highest mean concentrations were at W-3 WRA and South WRA at 108 mg/kg. The BCL for barium is 310 mg/kg and the RSL is 190,000 mg/kg.

<u>Beryllium</u>
Beryllium was detected in 92 percent of Native Alluvium samples, 33 to 100 percent in all WRAs and Arimetco HLPs samples, and infrequently (0 to 10 percent) in tailings samples. The minimum beryllium concentration of 0.08 mg/kg and the maximum of 2.6 mg/kg were both from the Arimetco HLPs. The mean beryllium concentration in Native Alluvium was 0.49 mg/kg, which was above the mean concentrations of all on-Site potential cover materials. The next highest mean was the South WRA at 0.44 mg/kg. The BCL for beryllium is 1.3 mg/kg and the RSL is 2,000 mg/kg.

Table 2. EPA Regional Screening Levels and Yerington Mine Background Concentration Limits			
Constituent	**Units**	**EPA Regional Screening Level Industrial Soil**	**Yerington Mine Background Concentration Limit**
Aluminum	mg/kg	990,000	25,436
Antimony	mg/kg	410[a]	1.8
Arsenic	mg/kg	1.6[b]	17
Barium	mg/kg	190,000	310
Beryllium	mg/kg	2,000	1.3
Boron	mg/kg	200,000	21
Cadmium	mg/kg	800[c]	0.35
Calcium	mg/kg	---	46,625
Chromium	mg/kg	5.6/1,500,000[d]	19
Cobalt	mg/kg	300	15
Copper	mg/kg	41,000	285
Iron	mg/kg	720,000	28,465
Lead	mg/kg	800	13
Magnesium	mg/kg	---	9,889
Manganese	mg/kg	23,000[e]	729
Mercury	mg/kg	34[f]	0.050
Molybdenum	mg/kg	5,100	3.3
Nickel	mg/kg	20,000[g]	18
Potassium	mg/kg	---	5,229
Selenium	mg/kg	5,100	0.87
Silver	mg/kg	5,100	0.58
Sodium	mg/kg	---	2,407
Thallium	mg/kg	---	0.60
Thorium	mg/kg	172[h]	19
Uranium	mg/kg	4.92[i]	4.1
Vanadium	mg/kg	5,200	65
Zinc	mg/kg	310,000[j]	62
Radium-226	pCi/g	2.48[k]	2.44
Radium-228	pCi/g	5.38[k]	2.13

Source: EPA Regions 3, 6, and 9. (November 2010). Regional Screening Levels for Chemical Contaminants at Superfund Sites.
a = antimony (metallic)
b = arsenic (inorganic)
c = cadmium (non-diet)
d = chromium (VI) / chromium (III) insoluble salts
e = manganese (diet)
f = mercury (elemental)
g = nickel (soluble salts)
h = based on radionuclide Preliminary Remediation Goal (PRG) for thorium-232
i = based on radionuclide PRG for uranium-238+D
j = zinc (metallic)
k = values based on radionuclide PRGs at the 1E-4 risk level with decay products included

<u>Boron</u>

Boron was detected in 38 percent of Native Alluvium samples, but was typically detected more frequently (80 to 100 percent) in on-Site potential cover material samples. Two exceptions were the Oxide Tailings, which had two percent boron detections and the S-23 WRA, which had 33 percent. The minimum boron concentration of 2.4 mg/kg and the maximum of 38 mg/kg were both from the Native Alluvium. The mean boron concentration in Native Alluvium was 10 mg/kg, which was above the mean concentrations of all on-Site potential cover materials except for Arimetco HLPs at 15 mg/kg. The BCL for boron is 21 mg/kg and the RSL is 200,000 mg/kg.

Cadmium

Cadmium was only detected in W-3 WRA and Arimetco HLPs samples, and the detection frequency range was 12 to 25 percent. The minimum cadmium concentration of 0.03 mg/kg was from the Arimetco HLPs and the maximum of 3.0 mg/kg was from the W-3 WRA. The mean cadmium concentration was 2.3 mg/kg for the W-3 WRA and 0.86 mg/kg for the Arimetco HLPs. The BCL for cadmium is 0.35 mg/kg and the RSL for cadmium (non-diet) is 800 mg/kg.

Calcium

Calcium was detected in all potential cover material samples. The minimum calcium concentration of 1,300 mg/kg was from the Oxide Tailings and the maximum of 79,000 mg/kg was from the Native Alluvium. The mean calcium concentration in Native Alluvium was 8,322 mg/kg, higher than the mean concentrations of on-Site potential cover materials. The next highest mean value was from the Arimetco HLPs at 7,285 mg/kg. The BCL for calcium is 46,625 mg/kg (there is no published RSL for calcium).

Chromium

Chromium was detected in only 78 percent of Native Alluvium samples, but was detected in all potential on-Site cover material samples. The minimum chromium concentration of 1.8 mg/kg was from the Native Alluvium and the maximum of 230 mg/kg was from the W-3 WRA. The mean chromium concentration in Native Alluvium was 6.6 mg/kg, which was below the mean concentrations of all on-Site potential cover materials except for the Sulfide Tailings at 5.5 mg/kg and the Arimetco HLPs at 5.6 mg/kg. The W-3 WRA had the highest mean at 30 mg/kg. The BCL for chromium is 19 mg/kg and the RSL is 5.6 mg/kg (as chromium VI) or 1,500,000 mg/kg (as chromium III insoluble salts).

Cobalt

Cobalt was detected in all but seven potential cover material samples. The minimum cobalt concentration of 1.7 mg/kg and the maximum of 69 mg/kg were both from the Arimetco HLPs. The mean concentration in Native Alluvium was 5.4 mg/kg (comparable to the means of other on-Site potential cover materials). The Arimetco HLPs had the highest mean at 8.4 mg/kg. The BCL for cobalt is 15 mg/kg and the RSL is 300 mg/kg.

Copper

Copper was detected in all potential cover material samples. The minimum copper concentration of 4.5 mg/kg was from the Native Alluvium and the maximum of 10,400 mg/kg was from the Arimetco HLPs. The mean copper concentration in Native Alluvium (47 mg/kg) was below the mean concentrations of all on-Site potential cover materials. The highest mean was the S-23 WRA at 3,367 mg/kg. The BCL for copper is 285 mg/kg and the RSL is 41,000 mg/kg.

Iron

Iron was detected in all potential cover material samples. The minimum iron concentration of 5,200 mg/kg was from the S-23 WRA and the maximum of 61,100 mg/kg was from Arimetco HLPs. The mean iron concentration in Native Alluvium was 12,596 mg/kg (comparable to the means of the on-Site potential cover materials). The Arimetco HLPs had the highest mean at 16,723 mg/kg. The BCL for iron is 28,465 mg/kg and the RSL is 720,000 mg/kg.

Lead

Lead was detected in all potential cover material samples. The minimum lead concentration of 1.7 mg/kg was from the Sulfide Tailings and the maximum of 1,000 mg/kg was from the W-3 WRA. The mean lead concentration in Native Alluvium was 5.7 mg/kg, which was comparable to the means of the on-Site potential cover materials, with one exception. The W-3 WRA had the highest mean at 89 mg/kg. The BCL for lead is 13 mg/kg and the RSL is 800 mg/kg.

Magnesium
Magnesium was detected in all potential cover material samples. The minimum magnesium concentration of 1500 mg/kg was from the Native Alluvium and the maximum of 19,800 mg/kg was from the Arimetco HLPs. The mean magnesium concentration in Native Alluvium was 3,599 mg/kg, below the mean concentrations of all on-Site potential cover materials. The highest mean was the Oxide Tailings at 6,137 mg/kg. The BCL for magnesium is 9,889 mg/kg (there is no published RSL for magnesium).

Manganese
Manganese was detected in all potential cover material samples. The minimum concentration of 26 mg/kg was from the Oxide Tailings and the maximum of 1,300 mg/kg was from the Native Alluvium. The mean manganese concentration in Native Alluvium was 249 mg/kg, above the mean concentrations of all on-Site potential cover materials. The next highest mean was the South WRA at 206 mg/kg. The BCL for manganese is 729 mg/kg and the RSL for manganese (diet) is 23,000 mg/kg.

Mercury
Mercury was detected in 12 percent of Native Alluvium samples, and in all but five potential on-Site cover material samples. The minimum mercury concentration of 0.008 mg/kg was from the South WRA and the maximum of 5.1 mg/kg was from the Arimetco HLPs. The mean mercury concentration in Native Alluvium was 0.031 mg/kg, below the means of other on-Site materials. Arimetco HLPs had the highest mean at 0.55 mg/kg. The BCL for mercury is 0.05 mg/kg and the RSL for elemental mercury is 34 mg/kg.

Molybdenum
Molybdenum was detected in 52 percent of Native Alluvium samples, but was detected more frequently (60 to 100 percent) in on-Site potential cover material samples. The minimum concentration of 0.41 mg/kg was from Native Alluvium and the maximum of 21 mg/kg was from the S-23 WRA. The mean concentration in Native Alluvium was 1.0 mg/kg, below the means of other on-Site potential cover materials. S-23 WRA had the highest mean at 12.7 mg/kg. The BCL for molybdenum is 3.3 mg/kg and the RSL is 5,100 mg/kg.

Nickel
Nickel was detected in 92 to 100 percent of potential cover materials. The minimum nickel concentration of 0.63 mg/kg was from the Arimetco HLPs and the maximum of 160 mg/kg was from the W-3 WRA. The mean concentration in Native Alluvium was 6.5 mg/kg, below the means of other on-Site potential cover materials. The BCL for nickel is 18 mg/kg and the RSL for nickel (soluble salts) is 20,000 mg/kg.

Potassium
Potassium was detected in all potential cover materials. The minimum potassium concentration of 440 mg/kg was from the Oxide Tailings and the maximum of 14,600 mg/kg was from the Arimetco HLPs. The mean potassium concentration in Native Alluvium was 1,661 mg/kg, above the means of other on-Site potential cover materials. The potassium BCL is 5,229 mg/kg (there is no published RSL for potassium).

Selenium
Selenium was detected in three percent of Native Alluvium samples and more frequently (20 to 100 percent) in on-Site potential cover materials. The minimum concentration of 0.47 mg/kg was from the Arimetco HLPs and the maximum of 320 mg/kg was from the W-3 WRA. The mean concentration in Native Alluvium was 1.0 mg/kg, below the means of other on-Site potential cover materials. W-3 WRA had the highest mean at 39 mg/kg. The BCL for selenium is 0.87 mg/kg and the RSL is 5,100 mg/kg.

Silver
Silver was not detected in Native Alluvium, Sulfide Tailings, W-3 WRA and South WRA samples, was detected once in the Oxide Tailings, and was detected more frequently (53 and 67 percent) in the remaining potential cover materials. The minimum silver concentration of 0.09 mg/kg was from the Arimetco HLPs and the maximum of 0.63 mg/kg was from the S-23 WRA. S-23 WRA had the highest mean at 0.46 mg/kg. The BCL for silver is 0.58 mg/kg and the RSL is 5,100 mg/kg.

Sodium

Sodium was detected in most samples. The minimum sodium concentration of 47 mg/kg was from the Sulfide Tailings and the maximum of 23,000 mg/kg was from the W-3 WRA. The mean sodium concentration in Native Alluvium was 559 mg/kg, which was above the means of other on-Site potential cover materials, with one exception. W-3 WRA had the highest mean at 3,441 mg/kg. The BCL for sodium is 2,407 mg/kg (there is no published RSL for sodium).

Thallium

Thallium was detected infrequently (0 to 14 percent) in Native Alluvium, tailings, and WRAs, but detected more frequently (67 percent) in Arimetco HLPs. The minimum thallium concentration of 0.42 mg/kg was from the Native Alluvium and the maximum of 2.5 mg/kg was from the Arimetco HLPs. The mean thallium concentration in Native Alluvium was 0.58 mg/kg, which was mid-range for the mean concentrations of on-Site potential cover materials. The Oxide Tailings had the highest mean value at 1.0 mg/kg. The BCL for thallium is 0.60 mg/kg (there is no published RSL for thallium).

Thorium

Thorium was detected in all potential cover material samples. The minimum thorium concentration of 3.5 mg/kg was from the Oxide Tailings and the maximum of 28 mg/kg was from the Native Alluvium. The mean thorium concentration in Native Alluvium was 8.0 mg/kg, which was mid-range for the mean concentrations of on-Site potential cover materials. The S-23 WRA had the highest mean at 11 mg/kg. The BCL for thorium is 19 mg/kg and the RSL is 172 mg/kg (based on the radionuclide EPA Preliminary Remediation Goal [PRG] for thorium-232).

Uranium

Uranium was detected in all potential cover material samples. The minimum uranium concentration of 0.57 mg/kg was from the Native Alluvium and the maximum of 11 mg/kg was from the South WRA. The mean uranium concentration in Native Alluvium was 1.4 mg/kg, which was below the means of the on-Site potential cover materials. The S-23 WRA had the highest mean at 3.6 mg/kg. The BCL for uranium is 4.1 mg/kg and the RSL is 4.92 mg/kg (based on the radionuclide PRG for uranium-238 plus daughters).

Vanadium

Vanadium was detected in all potential cover material samples. The minimum vanadium concentration of 7.3 mg/kg and the maximum of 66 mg/kg were both from the Native Alluvium. The mean vanadium concentration in Native Alluvium was 28 mg/kg. The South WRA had the next highest mean at 33 mg/kg. The BCL for vanadium is 65 mg/kg and the RSL is 5,200 mg/kg.

Zinc

Zinc was detected frequently (79 to 100 percent) of all potential cover material samples except for the Oxide Tailings (27 percent). The minimum zinc concentration of 6.1 mg/kg was from the Arimetco HLPs and the maximum of 1,800 mg/kg was from the Oxide Tailings. The mean zinc concentration in Native Alluvium was 29 mg/kg, which was mid-range for the mean concentrations of most on-Site potential cover materials. The Oxide Tailings had the highest mean at 166 mg/kg. The BCL for zinc is 62 mg/kg and the RSL for metallic zinc is 310,000 mg/kg.

Radium-226

Radium-226 was detected in all potential cover material samples. The minimum radium-226 concentration of 0.70 picoCuries per gram (pCi/g) was from the Native Alluvium and the maximum of 8.5 pCi/g was from the Oxide Tailings. The mean radium-226 concentration in Native Alluvium was 1.3 pCi/g, below the mean values of other on-Site potential cover materials. The Oxide Tailings had the highest mean at 3.7 pCi/g. The BCL for radium-226 is 2.44 pCi/g and the RSL is 2.48 pCi/g (based on radionuclide PRGs at the 1E-4 risk level with decay products included).

Radium-228

Radium-228 was detected in most potential cover material samples. The minimum radium-228 concentration of 0.56 pCi/g was from the Native Alluvium and the maximum of 3.5 pCi/g was from the W-3 WRA. The mean radium-228 concentration in Native Alluvium was 1.3 pCi/g, the mid-range of mean concentrations for on-Site potential cover materials. The S-23 WRA had the highest mean at 2.4 pCi/g. The BCL for radium-228 is 2.13 pCi/g and the RSL is 5.38 pCi/g (based on radionuclide PRGs at the 1E-4 risk level with decay products included).

Total metals and radiochemicals in the Native Alluvium can be characterized, relative to other on-Site potential cover materials, as:

- Elevated aluminum, barium, beryllium, boron, calcium, manganese, potassium, and vanadium;
- Low in chromium, copper, magnesium, mercury, molybdenum, nickel, selenium, uranium, and radium-226; and
- No detections of antimony, silver, and cadmium.

Conversely, total metals and radiochemicals in the on-Site potential cover materials can be characterized, relative to the Native Alluvium, as:

- Elevated chromium, copper, magnesium, mercury, molybdenum, and nickel; and
- Low in aluminum, barium, beryllium, boron, calcium, manganese, and sodium.

The following observations can be made regarding total metals and radiochemicals:

- Copper concentrations in the on-Site potential cover materials were 16 to 72 times higher than the Native Alluvium. The highest copper mean concentrations were found in the S-23 WRA at 3,367 mg/kg and the W-3 WRA at 1,685 mg/kg. The South WRA had the lowest mean copper concentration at 748 mg/kg.
- The South WRA had the majority of the minimum total metal and radiochemical detections, while the W-3 WRA had the majority of the maximum detections.
- The Oxide Tailings had consistently higher mean concentrations of total metals and radiochemicals compared to the Sulfide Tailings.

In addition to the finer-grained backhoe samples discussed above, twelve (12) rock grab samples were collected (four samples from each of the WRAs). Analytical results, lab reports and associated information, for these samples are provided in Attachment 3. Analytical results for rock samples from the W-3 and South WRAs were similar to results from corresponding backhoe samples. The S-23 WRA rock samples had higher maximum values (and typically higher mean values) for most analytes relative to backhoe samples. Analytical results of the rock samples from the WRAs are discussed below:

- Rock samples from the W-3 WRA exhibited higher maximum concentrations (and typically higher mean concentrations) than backhoe samples for nine of 27 total metals: aluminum (mean of 9,275 mg/kg); antimony (mean of 55 mg/kg); arsenic (mean of 12 mg/kg); beryllium (mean of 0.32 mg/kg); calcium (mean of 6,550 mg/kg); cobalt (mean of 6.0 mg/kg); copper (mean of 3,288 mg/kg); mercury (mean of 5.7 mg/kg); and uranium (mean of 2.0 mg/kg).

- S-23 WRA samples showed higher maximum concentrations (and higher mean concentrations) than backhoe samples for 15 of 27 total metals and one radiochemical: antimony (max. of 4.5 mg/kg); arsenic (mean of 5.5 mg/kg); boron (max. of 4.3 mg/kg); calcium (mean of 6, 050 mg/kg); chromium (mean of 31 mg/kg); cobalt (mean of 9.3 mg/kg); copper (mean of 2,625 mg/kg); iron (mean of 17,050 mg/kg); lead (mean of 2.6 mg/kg); mercury (mean of 0.19 mg/kg); potassium (mean of 1,700 mg/kg); selenium (mean of 3.9 mg/kg); sodium (mean of 121 mg/kg); thallium (mean of 0.38 mg/kg); uranium (mean of 3.8 mg/kg); and Ra-226 (mean of 2.2 pCi/g).

- Rock samples from the South WRA exhibited. higher maximum concentrations (and typically higher mean concentrations) than backhoe samples for eight of 27 total metals and two radiochemicals: boron (mean of 4.3 mg/kg); chromium (mean of 32 mg/kg); copper (mean of 4,895 mg/kg); molybdenum (mean of 6.2 mg/kg); selenium (mean of 11 mg/kg); silver (max. of 0.33 mg/kg); thorium (mean of 7.0 mg/kg); uranium (mean of 28 mg/kg); Ra-226 (mean of 5.1 pCi/g); and Ra-228 (mean of 1.4 pCi/g).

Meteoric Water Mobility Procedure (MWMP) Analytical Results

The MWMP (ASTM E2242; NDEP, 1990) was conducted to evaluate the potential for the mobilization of metals and radiochemicals from potential cover materials. The MWMP consists of a single-pass column leach test over a 24-hour period using Type II reagent-grade water of a quality and pH that reflects anticipated climate conditions in Nevada, including the Site. MWMP results, laboratory reports, summary statistical tables, and data summary graphics are provided in Attachment 4.

Analytes with a maximum detection in leachate from at least one potential cover material sample that exceeded a maximum contaminant level (MCL) are discussed below. Results are compared to Native Alluvium results, which may serve as a baseline. Per the Revised Work Plan, samples from the Arimetco HLPs were not subject to the MWMP and no new leachate data were generated for these potential cover materials. Any discussion of Arimetco leachate data presented below is based on pre-existing data collected by CH2M Hill (2008). Rock sample analytical results are presented a t the end of this sections.

<u>Aluminum</u>
Aluminum was detected in all but two leachate samples in all potential cover materials. The minimum aluminum concentration of 0.069 mg/L was from the W-3 WRA and the maximum of 2,170 mg/L was from the Arimetco HLPs. The mean concentration in Native Alluvium leachate was 15 mg/L, below the mean concentrations of all potential on-Site cover materials. The highest mean was form the Arimetco HLPs, at 397 mg/L. Aluminum has a primary MCL of 0.05 mg/L and a secondary MCL of 0.2 mg/L.

<u>Arsenic</u>
Arsenic was detected in all Native Alluvium and South WRA leachate samples, but less frequently (33 to 75 percent) in the other on-Site potential cover material samples. The minimum arsenic concentration of 0.0009 mg/L was from the Arimetco HLPs and the maximum of 0.18 mg/L was from the South WRA. The mean arsenic concentration in Native Alluvium leachate was 0.059 mg/L which was above the mean concentrations of all on-Site potential cover materials, except for the South WRA at 0.11 mg/L. Arsenic has a primary MCL of 0.01 mg/L.

<u>Beryllium</u>
Beryllium was detected in all Native Alluvium, W-3 WRA and South WRA leachate samples, but less frequently (67 to 90 percent) in the other on-Site potential cover material samples. The minimum beryllium concentration of 0.00012 mg/L was from the South WRA, and the maximum of 0.12 mg/L was from the Arimetco HLPs. The mean beryllium concentration in Native Alluvium leachate was 0.00051 mg/L, which was below the mean concentrations of all on-Site potential cover materials. The highest mean was from the S-23 WRA, at 0.037 mg/L. Beryllium has a primary MCL of 0.004 mg/L.

<u>Cadmium</u>
Cadmium was detected in 80 percent of Native Alluvium leachate samples, and in 33 to 100 percent of the on-Site potential cover material samples. The minimum cadmium concentration of 0.00014 mg/L was from the Native Alluvium samples and the maximum of 0.043 mg/L was from the Arimetco HLPs. The mean cadmium concentration in Native Alluvium leachate was 0.00035 mg/L which was below the mean concentrations of all on-Site potential cover materials. The highest mean was the Arimetco HLPs at 0.010 mg/L. Cadmium has a primary MCL of 0.005 mg/L.

Copper

Copper was detected in all leachate samples in all potential cover materials. The minimum copper concentration of 0.016 mg/L and the maximum of 610 mg/L were both from the S-23 WRA. The mean copper concentration in Native Alluvium leachate was 0.094 mg/L, which was considerably below the mean concentrations of other on-Site potential cover materials. The highest mean was the Oxide Tailings at 288 mg/L. Copper has a Treatment Technique Action Level (TTAL) of 1.3 mg/L.

Chromium

Chromium was not detected in the S-23 WRA leachate samples and in 33 to 80 percent of the other potential cover material samples. The minimum chromium concentration of 0.0009 mg/L was from the Oxide Tailings and the maximum of 0.16 mg/L was from Arimetco HLPs. The mean chromium concentration in Native Alluvium leachate was 0.0062 mg/L and the highest mean was from the Arimetco HLPs at 0.068 mg/L. Chromium has a primary MCL of 0.1 mg/L.

Iron

Iron was detected in all Native Alluvium and South WRA leachate samples, but less frequently (30 to 90 percent) in other on-Site potential cover materials. The minimum iron concentration of 0.063 mg/L was from the Sulfide Tailings and the maximum was from the South WRA at 77 mg/L. The mean iron concentration in Native Alluvium leachate was 11 mg/L, which was above the mean concentrations of other on-Site potential cover materials except for the South WRA at 39 mg/L. Iron has a secondary MCL of 0.3 mg/L.

Lead

Lead was detected in all Native Alluvium leachate samples, but less frequently (0 to 90 percent) in the on-Site potential cover material samples. The minimum lead concentration of 0.00020 mg/L was found in the Arimetco HLPs, and the maximum of 0.021 mg/L was from the South WRA. The mean lead concentration in Native Alluvium leachate was 0.0041 mg/L, which was above the mean concentrations of all on-Site potential cover materials except for the South WRA at 0.011 mg/L. The South WRA was the only potential cover material with a detection that exceeded the TTAL for lead of 0.015 mg/L.

Manganese

Manganese was detected in all but one leachate sample. The minimum manganese concentration of 0.039 mg/L was from the South WRA and the maximum of 59 mg/L was from the Arimetco HLPs. The mean manganese concentration in Native Alluvium leachate was 0.11 mg/L, which was below the mean concentrations of other on-Site potential cover materials. The highest mean was the Sulfide Tailings at 16 mg/L. Manganese has a secondary MCL of 0.05 mg/L.

Mercury

Mercury was detected in 80 percent of Native Alluvium leachate samples, but less frequently (0 to 70 percent) in the on-Site potential cover materials. The minimum mercury concentration of 0.00011 mg/L was found in the Native Alluvium samples, and the maximum of 0.039 mg/L was from the Arimetco HLPs. The mean mercury concentration in Native Alluvium leachate was 0.00012 mg/L, below the mean concentrations of potential on-Site cover materials except for the Sulfide Tailings that had no detections. The Arimetco HLPs had the highest mean mercury concentration at 0.013 mg/L. The W-3 WRA and Arimetco HLPs had samples with detections that exceeded the primary MCL for mercury of 0.002 mg/L.

Selenium

Selenium was detected in all Native Alluvium and Sulfide Tailings leachate samples, but less frequently (67 to 90 percent) in other on-Site potential cover material samples. The minimum selenium concentration of 0.00064 mg/L was from the South WRA and the maximum of 0.28 mg/L was from the W-3 WRA. The mean concentration in Native Alluvium leachate was 0.0017 mg/L, which was below the mean concentrations of all other potential on-Site cover materials with the exception of the South WRA. The highest mean was the W-3 WRA at 0.095 mg/L. Selenium has a primary MCL of 0.05 mg/L.

Thallium

Thallium was not detected in any Native Alluvium and S-23 WRA leachate samples, and was detected infrequently (25 to 80 percent) in the on-Site potential cover material samples. The minimum thallium concentration of 0.00010 mg/L was from the Arimetco HLPs and the maximum of 0.0086 mg/L was from the Oxide Tailings. The highest mean value was the Oxide Tailings at 0.0031 mg/L. The Oxide Tailings was the only potential cover material with a detection that exceeded the MCL for thallium (0.0020 mg/L).

Uranium

Uranium was detected in all leachate samples. The minimum uranium concentration of 0.0013 mg/L was found in the W-3 WRA, and the maximum of 0.30 mg/L was from the S-23 WRA. The mean uranium concentration in Native Alluvium leachate was 0.0044 mg/L, below the mean concentrations of other potential on-Site cover materials. The highest mean was the S-23 WRA at 0.13 mg/L. The S-23 WRA, W-3 WRA, Oxide Tailings and Sulfide Tailings all had detections that exceeded the MCL for uranium (0.03 mg/L).

Zinc

Zinc was detected in all but one leachate samples. The minimum zinc concentration of 0.008 mg/L was from the S-23 WRA and the maximum of 5.0 mg/L was from the Arimetco HLPs. The mean zinc concentration in Native Alluvium leachate was 0.028 mg/L which was below the mean concentrations of all on-Site potential cover materials. The highest mean was the Arimetco HLPs at 1.2 mg/L (one HLP sample had a value at the secondary MCL of 5.0 mg/L).

Radium-226

Radium-226 was detected in all but two leachate samples. The minimum radium-226 value of 0.159 pCi/L was from the Sulfide Tailings and the maximum of 10 pCi/L was from the South WRA. The mean radium-226 concentration in Native Alluvium leachate was 0.092 pCi/L, which was below the mean values for other on-Site samples (except the S-23 WRA). The highest mean value was from the South WRA (3.8 pCi/L), with one sample exceeding the MCL of 5.0 pCi/L (combined MCL for radium-226 and -228).

For Native Alluvium samples, every metal was detected in leachate except for thallium. Only four metals (aluminum, arsenic, iron, and manganese) had maximum detections in leachate that exceeded MCLs. The mean concentrations of the leachate for these four metals also exceeded the MCLs. Metals in the Native Alluvium leachate can be characterized (relative to on-Site potential cover materials) as:

- Elevated arsenic, barium, boron, lead, silver, sodium, and vanadium;
- Low in aluminum, beryllium, cadmium, calcium, cobalt, copper, magnesium, manganese, mercury, nickel, selenium, uranium, and zinc; and
- No thallium detections.

Leachate from on-Site materials exceeded MCLs for aluminum, arsenic, beryllium, cadmium, chromium, copper, iron, manganese, mercury, selenium, thallium, uranium and radium-226. Typically, mean concentrations of the leachate for these parameters also exceeded the MCLs. Metals in the on-Site potential cover materials leachate can be characterized (relative to the Native Alluvium leachate) as:

- Elevated aluminum, beryllium, cadmium, calcium, cobalt, copper, magnesium, manganese, mercury, nickel, selenium, thallium, uranium, and zinc; and
- Low in arsenic, barium, boron, lead, silver, sodium, and vanadium.

The following observations can be made regarding metals in leachate from on-Site samples:

- Leachate from the South WRA more closely resembled leachate from the Native Alluvium rather than other on-Site potential cover materials in two ways: 1) South WRA leachate was elevated in arsenic, barium, boron, lead, silver, sodium, and vanadium; and 2) South WRA leachate had the next fewest MCL exceedances behind the Native Alluvium.

- Copper concentrations in the on-Site potential cover material leachate samples were 100 to 3,000 times higher than from the Native Alluvium samples. The highest copper leachate mean concentrations were found in the Oxide Tailings at 288 mg/L and the S-23 WRA at 280 mg/L. The South WRA had the lowest copper leachate mean concentrations near 1 mg/L.
- The South WRA had the majority of the minimum leachable metals detections, and the Arimetco HLPs had the majority of the maximum detections. The highest mean concentrations were also typically from the Arimetco HLP leachate samples.

In addition to the finer-grained backhoe samples discussed above, 12 rock samples (four from each of the WRAs) were subjected to the MWMP and leachate analysis for total metals and radiochemicals. Leachate analytical results, lab reports, etc., and associated information are provided in Attachment 4. In general, MWMP leachate results for rock grab samples had similar or fewer exceedances of MCLs or TTALs than backhoe sample results, as described below:

- Leachate from the W-3 WRA samples had four metals that exceeded MCLs or TTALs: aluminum (up to 3.0 mg/L); copper (up to 9.1 mg/L); iron (up to 13 mg/L); and manganese (up to 0.66 mg/L). In comparison, backhoe sample results indicated 10 metals with MCL/TTAL exceedances: aluminum; arsenic; beryllium; chromium; copper; iron; manganese; mercury; selenium; uranium.
- Leachate from rock samples from the S-23 WRA exhibited seven metals that exceeded MCLs or TTALs: aluminum (up to 120 mg/L); beryllium (up to 0.029 mg/L); copper (up to 250 mg/L); iron (up to 22 mg/L); manganese (up to 3.5 mg/L); selenium (0.09 mg/L); and uranium (up to 0.49 mg/L). In comparison, backhoe sample leachate had six metals that exceeded MCLs/TTALs: aluminum; beryllium; copper; manganese; selenium; uranium.
- South WRA rock sample leachate exhibited five metals that exceeded MCLs/TTALs: aluminum (up to 2.5 mg/L); copper (up to 93 mg/L); iron (up to 2.0 mg/L); manganese (up to 0.69 mg/L); and uranium (up to 0.002 mg/L). In comparison, backhoe sample leachate had seven metals that exceeded MCLs/TTALs: aluminum; arsenic; copper; iron; lead; manganese; and radium-226.

Acid Generation Potential Results

The acid generating potential of each sample was evaluated using the modified Sobek method (Lawrence and Wang, 1997; Appendix D-2) and the NAG test. ABA and NAG tests were performed on a portion of the samples collected in the 5-gallon buckets prepared for the MWMP. SEM also determined the paste pH values for each sample. ABA results are reported as net neutralization potential (NNP) and neutralization potential ratio (NPR). Summary tables presented below provide general ratings based on the range of values for each sample.

As described in EPA (2003), acid generation potential (AGP) is determined from the sulfur content of a sample (expressed in weight percent). This value is converted to AGP by multiplying by a factor of 31.25 that is derived from the molar stoichiometry of the oxidation and neutralization reactions. The conversion factor assumes that all reported sulfur occurs as pyrite, that pyrite is completely oxidized to sulfate and ferric hydroxide, and that hydrogen ions produced in the oxidation reaction are neutralized by $CaCO3$. Acid generating potential is reported in kilograms of $CaCO3$ equivalent per metric ton of sample (also expressed in units of metric tons of CaCo3 equivalent per kilotonne of material).

Static test results are generally interpreted within an empirically developed framework. Interpretations are based on the net neutralization potential (NNP) and the neutralization potential ratio (NPR). The NNP is defined as the difference between the acid neutralization potential (NP) and AGP of a sample. It is computed by subtracting the latter from the former (NP-AGP) when both are expressed in units of kilograms of $CaCO3$ equivalent per metric ton of material (or metric tons per kiloton).

NPR is the ratio of acid neutralizing potential to acid generation potential (NP/AGP) and is computed from static test results when both are expressed in units of kilograms of CaCO3 equivalent per metric ton of material (or metric tons per kiloton). NNP values are reported in kilograms of calcium carbonate per ton (kg $CaCO_3$/t) or, equivalently, as tons of calcium carbonate per kiloton (t $CaCO_3$/kt). NPR is reported as a unit less parameter. Table 3 provides guidelines for predicting whether a material is potentially acid generating (PAG), as described by Price et al. (1997). The NPR value of "4" in Table 3 may be overly conservative.

Table 3. Guidelines for Prediction of Acid Rock Drainage		
ABA Parameter	**Criteria**	**Prediction**
NNP (kg $CaCO_3$/t)	< -20	PAG
	> -20 and < 20	uncertain PAG
	> 20	non-PAG
NPR (unit less)	< 1	PAG
	> 1 and < 4	uncertain PAG
	> 4	non-PAG

ABA Results

NNP test results (values presented as kg $CaCO_3$ per ton) are summarized in Table 4 by potential cover material type, including rock grab samples from the WRAs. Native Alluvium exhibited the lowest potential for acid generation (values ranging from 4.0 to 35 kg $CaCO_3$/t and a mean of 18 kg $CaCO_3$/t), followed by South WRA materials with values (excluding one outlier of -13 kg $CaCO_3$/t) from 7.0 to 17 kg $CaCO_3$/t and a mean of 11 kg $CaCO_3$/t. Oxide and sulfide tailings, S-23 and W-3 WRA materials, and Arimetco HLPs yielded uncertain potential or were classified as PAG with values as low as -34 kg/kg $CaCO_3$/t.

Table 4. Net Neutralization Potential Analytical Summary							
Potential Cover Material	**Count**	**Min.**	**Mean**	**Max.**	**Std. Dev.**	**Median**	**PAG Prediction**
Native Alluvium	5	4.0	18	35	11	18	uncertain/non-PAG
Oxide Tailings	10	-2.1	0.39	3.0	1.6	0.0	uncertain
Sulfide Tailings	3	0.80	6.3	12	5.8	5.8	uncertain
W-3 WRA	3	-2.2	0.30	3.1	2.7	0.0	uncertain
W-3 WRA - Rock	4	-98	-23	3.0	50	2.5	PAG/uncertain
S-23 WRA	3	0.70	11	22	11	8.9	uncertain/non-PAG
S-23 WRA - Rock	4	-54	-15	9.6	28	-8.4	PAG/uncertain
South WRA	5	7.0	11	17	4.4	10	uncertain
South WRA - Rock	4	-13	-1.4	4.0	7.9	1.8	uncertain
Phase I/II HLP	4	-19	-15	-12	3.4	-14	uncertain
Phase III South HLP	8	-28	-22	-18	2.9	-23	PAG/uncertain
Phase III 4X HLP	4	-24	-14	-6	7.5	-13	PAG/uncertain
Phase IV Slot HLP	3	-34	-26	-20	7.4	-23	PAG
Phase IV VLT HLP	6	-33	-17	-1	12	-18	PAG/uncertain

In general, the rock samples exhibited a greater potential for acid generation than backhoe samples, as described below:

- W-3 WRA rock samples had NNP values that were considerably lower (approaching -98 kg $CaCO_3$/t) compared to backhoe samples and higher NAG values (up to 29 kg $CaCO_3$/t) compared to backhoe samples. These results generally indicate PAG materials.

- S-23 WRA rock samples had NNP values that were considerably lower (approaching -54 kg $CaCO_3$/t) compared to backhoe samples, and higher NAG values (up to 11 kg $CaCO_3$/t) compared to backhoe samples. These results generally indicate PAG materials, but to a lesser degree than the W-3 WRA materials.

- South WRA rock samples had NNP values that were lower (approaching -13 kg $CaCO_3$/t) compared to backhoe samples, and higher NAG values (up to 3 kg $CaCO_3$/t) compared to backhoe samples. These results generally indicate PAG materials, but to a lesser degree than the other two WRAs.

NAG Test Results

The NAG test (Stewart et. al., 2006) estimates the net amount of acid generated by the oxidation of the material as a result of oxidative weathering. The NAG test is generally used to confirm ABA results and ascertain whether theoretical acid generating potential and neutralization potential would be generated and available when the material undergoes oxidation. The criteria for interpretation of NAG results are provided in Table 5, from Miller et al. (1997).

Table 5. Criteria for Interpretation of NAG Results

NAG pH	NAG Value	NNP	Prediction
< 4	< 10	Negative	PAG (low capacity)
< 4	> 10	Negative	PAG (high capacity)
≥ 4	0	Negative	Uncertain PAG
≥ 4	0	Positive	Non-PAG

The results of the NAG test (values presented in kg $CaCO_3$ per ton) are summarized in Table 6 by potential cover material type. The NAG testing generally confirmed the ABA testing. There were only four non-zero NAG results ranging from 3.0 to 29 kg $CaCO_3$/t. Only one of 14 samples from the Native Alluvium and South WRA had a positive NAG result (3.0 kg $CaCO_3$/t). These NAG results, combined with nearly all positive NNP values, indicate these potential cover materials have low potential for acid generation (non-PAG or uncertain PAG).

The tailings, other WRAs (finer grained materials), and Arimetco HLPs had NAG results that were nearly all zero and these materials have either uncertain potential for acid generation or were classified as non-PAG. The rock samples from the WRAs exhibited significantly greater NAG values than the finer grained samples, and were classified as PAG or as having uncertain potential for acid generation.

Paste pH

Equal masses of pulverized sample and water were mixed together to create a wet paste to determine pH (saturated paste). The results of the paste pH test are summarized in Table 7 by potential cover material type. The following criteria may be used for the general rating for paste pH values: less than 4 = very acidic, 4 to 6 = acidic, 6 to 8 = neutral pH, 8 to 10 = basic, greater than 10 = very basic.

Table 6. Net Acid Generation Analytical Summary								
Potential Cover Material	Count	Detects	Min.	Mean	Max.	Std. Dev.	Median	PAG Prediction
Native Alluvium	5	0	< 1.0	NC	< 1.0	NC	NC	non-PAG
Oxide Tailings	10	0	< 1.0	NC	< 1.0	NC	NC	uncertain/non- PAG
Sulfide Tailings	3	0	< 1.0	NC	< 1.0	NC	NC	non-PAG
W-3 WRA	3	0	< 1.0	NC	< 1.0	NC	NC	uncertain/non-PAG
W-3 WRA - Rock	4	1	29	NC	29	NC	NC	PAG/uncertain
S-23 WRA	3	0	< 1.0	NC	< 1.0	NC	NC	non-PAG
S-23 WRA - Rock	4	2	11	13	15	2.8	13	PAG/uncertain
South WRA	5	0	< 1.0	NC	< 1.0	NC	NC	non-PAG
South WRA - Rock	4	1	3.0	NC	3.0	NC	NC	uncertain PAG

NC = not calculated

Table 7. Paste pH (saturated) Analytical Summary							
Potential Cover Material	Count	Min.	Mean	Max.	Std. Dev.	Median	General Rating
Native Alluvium	5	8.8	9.0	9.2	0.15	9.0	Basic
Oxide Tailings	10	5.0	5.9	6.6	0.45	5.9	Acidic
Sulfide Tailings	3	6.5	7.6	8.3	0.92	7.9	near neutral pH
W-3 WRA	3	5.7	6.4	7.6	1.0	5.9	acidic to slightly basic
W-3 WRA - Rock	4	6.8	7.3	8.4	0.7	7.0	near neutral pH
S-23 WRA	3	5.5	6.8	8.1	1.3	6.7	acidic to slightly basic
S-23 WRA - Rock	4	4.4	6.2	8.4	1.7	6.0	acidic to slightly basic
South WRA	5	8.2	9.0	9.3	0.40	9.1	slightly basic to basic
South WRA - Rock	4	5.4	7.7	8.9	1.6	8.3	acidic to basic

Plant Growth Parameter Results

Potential cover materials were evaluated for the analytical parameters listed in Table 8 for their potential to support volunteer or designed plant growth. These cover material samples were analyzed by A&L Western Agricultural Laboratory in Modesto, California, using the methods indicated. This discussion of cover material suitability to support plant growth begins with analysis and discussion of pH because plants cannot tolerate extremely acidic (pH <4.5) soil conditions because of hydrogen ion toxicity and indirect effects of naturally occurring, but toxic, acid-soluble clay constituents (aluminum, iron and manganese). Soil acidity, aluminum and iron toxicity typically cause stunted roots, exacerbating uptake of soil moisture and nutrients, leading to stunted plants and overall poor vigor. Other soil chemical parameters including organic matter content, cation exchange capacity (CEC), sodium adsorption ratio (SAR), nitrogen, phosphorus, cations (calcium, magnesium, potassium) affect plant growth if soil pH can be increased to a minimum of pH 5.5.

Soil pH

Soil pH is measured by adding de-ionized water to make a “saturated paste”, inserting a pH electrode into the paste, and recording the pH reading. The following are general ratings for soil pH: 5.0 or below is “very low”; 5.1–6.0 is “low”; 6.1–7.5 is “medium”; 7.6–8.5 is “high”; and 8.6–10.0 is “very high”. The results of soil pH are summarized in Table 9 by potential cover material type. Buffer index (i.e., lime requirement) is a measure of both active and reserve acidity. Soil pH can be correlated to the quantity of $CaCO_3$ (lime) required to increase the pH to 7.0 (Shoemaker et. al., 1965).

Table 8. Plant Growth Parameters and Analytical Methods	
Parameter	**Analytical Method**
Soil pH	NAPT S-1.10
Calcium, Magnesium and Sodium	NAPT S-5.10
Sodium Adsorption Ratio (SAR)	NAPT S-1.60
Organic Matter and Total Organic Carbon	NAPT S-9.20 and S-1.30
Cation Exchange Capacity (CEC)	NAPT S-10.10
Soluble Salts (dS/m)	NAPT S-1.20
Total Kjeldahl Nitrogen (TKN)	NAPT S-8.10
Nitrogen, Phosphorus, and Potassium (NPK)	NAPT S-4.20 (Weak Bray) and S-4.10 (Olsen)

NAPT = North American Proficiency Testing Program

Among the various potential cover material types, the off-Site alluvial materials exhibit the optimal soil pH with values ranging from 7.5 to 8.3 units (medium to high). The Oxide Tailings, W-3 WRA and Arimetco HLPs had the most acidic soil pH results, with averages typically at 4.0 or less (very low to low). The Sulfide Tailings and S-23 WRA have low to medium soil pH values, with averages near 5.0. The South WRA was unique in that it had the most alkaline soil pH results ranging from 8.0 to 9.1 (high to very high).

Table 9. Soil pH Analytical Summary								
Potential Cover Material	**Units**	**Count**	**Min.**	**Mean**	**Max.**	**Std. Dev.**	**Median**	**General Rating**
Native Alluvium	units	5	7.5	8.1	8.3	0.33	8.1	medium to high
Oxide Tailings	units	3	3.8	4.0	4.2	0.20	4	very low
Sulfide Tailings	units	3	4.1	5.1	6.8	1.5	4.3	very low to medium
W-3 WRA	units	3	3.4	4.1	5.4	1.1	3.6	very low to low
S-23 WRA	units	3	4.1	5.3	7.5	1.9	4.4	very low to medium
South WRA	units	5	8.0	8.8	9.1	0.45	9	high to very high
Phase I/II HLP	units	7	3.4	3.5	3.7	0.10	3.5	very low
Phase III South HLP	units	6	3.4	4.1	7.1	1.5	3.52	very low to medium
Phase III 4X HLP	units	6	3.3	3.7	4.1	0.31	3.65	very low
Phase IV Slot HLP	units	6	3.5	3.8	4.4	0.37	3.57	very low
Phase IV VLT HLP	units	6	3.3	3.5	3.7	0.16	3.535	very low

Samples collected from W-3 WRA and S-23 WRAs are fine-grained materials (no rock).

Calcium, Magnesium and Sodium

Results for calcium, magnesium, and sodium are presented as a: 1) concentration in parts per million (ppm) from an ammonium acetate extract; 2) percentage of total cations from an ammonium acetate extract; and 3) concentration in milliequivalents per liter (meq/L) from a saturated paste extract. Soils with 40-70% calcium, 10-20% magnesium, 5-10% potassium and less than 5% sodium can support plant growth, if soil pH, soil moisture, nitrogen and phosphorus are also present in acceptable ranges.

The following general ratings for calcium (percent cation saturation) are applicable to the potential cover materials: 35% and below is “very low”; 36 to 60% is “low”; 61 to 70% is “medium”; 71 to 75% is “high”; and 76 to 85% is “very high”. Calcium results (Table 10) indicate that alluvial materials had optimal calcium contents (68 to 83% saturation) and the remaining potential cover materials had considerably less calcium. General ratings for magnesium (percent cation saturation) are: 5% and below = “very low”; 6 to 10% = “low”; 11 to 20% = “medium”; 21 to 25% = “high”; and 26 to 35% = “very high”. Magnesium results are summarized in Table 11. Alluvial materials exhibited optimal magnesium contents of 7.6 to 20% saturation, and the remaining materials had considerably less magnesium content.

The following general ratings are for sodium (% cation saturation): 1% and below = "very low"; 2–3% = "low"; 4–5% = "medium"; 6–10% = "high"; and 11–30% = "very high". Sodium results (Table 12) indicate values below the optimal limit of 5% saturation. Native and South WRA alluvium samples had nearly twice the optimal limit (mean values of 10 to 12% saturation).

Table 10. Calcium Analytical Summary

Potential Cover Material	Units	Count	Min.	Mean	Max.	Std. Dev.	Median	General Rating
Native Alluvium	% sat.	5	68	76	83	7	76.9	medium to very high
Oxide Tailings	% sat.	3	21	22	24	2	21.4	very low
Sulfide Tailings	% sat.	3	23	46	87	36	28	very low to very high
W-3 WRA	% sat.	3	22	34	57	20	22.1	very low to low
S-23 WRA	% sat.	3	21	47	89	37	31.9	very low to very high
South WRA	% sat.	5	70	76	81	5	77.2	medium to very high
Phase I/II HLP	% sat.	2	21	n/a	22	n/a	n/a	very low
Phase III South HLP	% sat.	2	17	n/a	20	n/a	n/a	very low
Phase III 4X HLP	% sat.	2	20	n/a	22	n/a	n/a	very low
Phase IV Slot HLP	% sat.	2	22	n/a	23	n/a	n/a	very low
Phase IV VLT HLP	% sat.	2	19	n/a	20	n/a	n/a	very low

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

Table 11. Magnesium Analytical Summary

Potential Cover Material	Units	Count	Min.	Mean	Max.	Std. Dev.	Median	General Rating
Native Alluvium	% sat.	5	7.6	10	16	3.6	8.4	low to medium
Oxide Tailings	% sat.	3	3.2	4	4.4	0.7	3.2	very low
Sulfide Tailings	% sat.	3	2.8	6	8.1	2.7	5.6	very low to low
W-3 WRA	% sat.	3	2.6	5	11	4.6	3	very low to medium
S-23 WRA	% sat.	3	4.7	6	8.5	2.0	5.8	very low to low
South WRA	% sat.	5	7.7	12	20	5.1	9.1	low to medium
Phase I/II HLP	% sat.	2	3.2	n/a	3.7	n/a	n/a	very low
Phase III South HLP	% sat.	2	4.7	n/a	7.2	n/a	n/a	very low to low
Phase III 4X HLP	% sat.	2	2.9	n/a	4.4	n/a	n/a	very low
Phase IV Slot HLP	% sat.	2	1.6	n/a	3.3	n/a	n/a	very low
Phase IV VLT HLP	% sat.	2	4.8	n/a	5.4	n/a	n/a	very low

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

Table 12. Sodium Analytical Summary

Potential Cover Material	Units	Count	Min.	Mean	Max.	Std. Dev.	Median	General Rating
Native Alluvium	% sat.	5	4.9	12	21	6.2	12.7	medium to very high
Oxide Tailings	% sat.	3	0.2	0.4	0.6	0.2	0.3	very low
Sulfide Tailings	% sat.	3	0.2	0.5	1.1	0.5	0.3	very low
W-3 WRA	% sat.	3	0.2	1.0	2.7	1.4	0.2	very low to low
S-23 WRA	% sat.	3	0.1	0.6	1.5	0.8	0.1	very low to low
South WRA	% sat.	5	1.6	10	17	5.7	10.5	low to very high
Phase I/II HLP	% sat.	2	0.2	n/a	0.2	n/a	n/a	very low
Phase III South HLP	% sat.	2	0.2	n/a	0.4	n/a	n/a	very low
Phase III 4X HLP	% sat.	2	0.2	n/a	0.2	n/a	n/a	very low
Phase IV Slot HLP	% sat.	2	0.1	n/a	0.1	n/a	n/a	very low
Phase IV VLT HLP	% sat.	2	0.3	n/a	0.4	n/a	n/a	very low

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

Cation Exchange Capacity

CEC represents a soil's capacity to hold nutrients such as calcium, magnesium, and potassium (i.e., cations), as well as other positively-charged ions such as sodium and hydrogen. CEC is a pH-dependent parameter. For example, CEC may appear to be higher in an acid soil (pH 3-4) compared to the same soil after it is neutralized to pH 7. However, the high CEC value of an acid soil at pH 3-4, is due to "acid" cations (H+, Al+3, Fe+3), which are not nutrients and, in fact, are toxic to plants. In neutral soils, CEC is used as a measure of soil fertility and nutrient retention capacity.

CEC depends largely on the amount of clay and organic matter present. CEC is measured in milliequivalents per 100 grams of soil (meq/100g). The larger this value, the more cations the soil is able to hold against leaching. Most neutral soils have a CEC in the range of 5-20 meq/100g. Excessive levels of acidity (H^+, Al^{+3}, Fe^{+3}), or alkalinity (excess Calcium carbonate or sodium carbonate) will cause CEC to be over-estimated. CEC results are summarized in Table 13 by potential cover material type. For the potential cover material types evaluated, off-Site and South WRA alluvial materials exhibit a medium-to-high CEC with mean values near 20 meq/100g. These values are valid because the soil pH values for these materials are not acidic. For the remaining potential cover material types, which have acidic soil pH values (generally below 5.5), their CEC values are likely over-estimated and not a valid representation of the material's ability to hold nutrients or cations.

Table 13. Cation Exchange Capacity Analytical Summary

Potential Cover Material	Units	Count	Min.	Mean	Max.	Std. Dev.	Median	Soil pH Range	General Rating
Native Alluvium	meq/100g	5	13.4	24	31.9	7.3	27	7.5-8.3	medium to high
Oxide Tailings	meq/100g	3	70.9	81	97.6	14	75.7	3.8-4.2	likely over-estimated due to exchangeable H^+
Sulfide Tailings	meq/100g	3	7.2	35	55.4	25	42.4	4.1-6.8	likely over-estimated due to exchangeable H^{++}
W-3 WRA	meq/100g	3	20.3	80	114	52	105.1	3.4-5.4	likely over-estimated due to exchangeable H^+
S-23 WRA	meq/100g	3	12.1	34	50.2	20	40.9	4.1-7.5	likely over-estimated due to exchangeable H^+
South WRA	meq/100g	5	12.5	18	21.3	3.4	18.7	8.0-9.1	medium to high
Phase I/II HLP	meq/100g	2	108	n/a	163	n/a	n/a	3.4-3.7	likely over-estimated due to exchangeable H^+
Phase III South HLP	meq/100g	2	174	n/a	218	n/a	n/a	3.4-7.1	likely over-estimated due to exchangeable H^+
Phase III 4X HLP	meq/100g	2	107	n/a	111	n/a	n/a	3.3-4.1	likely over-estimated due to exchangeable H^+
Phase IV Slot HLP	meq/100g	2	140	n/a	222	n/a	n/a	3.5-4.4	likely over-estimated due to exchangeable H^+
Phase IV VLT HLP	meq/100g	2	101	n/a	159	n/a	n/a	3.3-3.7	likely over-estimated due to exchangeable H^+

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

Sodium Adsorption Ratio (SAR)

Elevated concentrations of sodium in soils are typically associated with saline-alkaline soils. Unlike the other potential cover materials tested, the native alluvium and the South WRA are not acid and the SAR test is appropriate. For saline-alkaline soils, a SAR value of 13 or higher indicates problems with low soil infiltration rate. The SAR is the proportion of sodium ion concentration compared to the concentration of calcium plus magnesium ions.

Although the concentrations of calcium, magnesium, and sodium are provided in meq/L for the SAR calculation, this is a unit less parameter. SAR results are summarized in Table 14 by potential cover material type. All potential cover material types, with the exception of the native alluvium and the South WRA samples, exhibited SAR results well below 13 and are not expected to present any problems associated with poor infiltration.

Table 14. Sodium Adsorption Ratio Analytical Summary

Potential Cover Material	Units	Count	Min.	Mean	Max.	Std. Dev.	Median	General Rating
Native Alluvium	None	5	2.6	5.5	8.6	2.8	4.4	low to medium
Oxide Tailings	None	3	0.6	0.7	0.7	0.06	0.7	Low
Sulfide Tailings	None	3	0.3	0.3	0.4	0.06	0.3	Low
W-3 WRA	None	3	0.3	0.5	0.8	0.3	0.4	Low
S-23 WRA	None	3	0.1	0.3	0.7	0.3	0.1	Low
South WRA	None	5	0.8	4.2	7.3	2.6	5.2	low to medium
Phase I/II HLP	None	5	0.03	0.2	0.5	0.2	0.075	Low
Phase III South HLP	None	4	0.06	0.5	1.2	0.6	0.4445	Low
Phase III 4X HLP	None	4	0.03	0.3	0.6	0.3	0.255	Low
Phase IV Slot HLP	None	4	0.03	0.4	0.8	0.4	0.324	Low
Phase IV VLT HLP	None	4	0.07	0.5	1.0	0.5	0.4445	Low

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

<u>Organic Matter and Total Organic Carbon</u>

Organic matter is expressed in percent. It measures the amount of recognizable undegraded plant parts (roots, stem, seeds) as well as decomposed plant and animal residues in soil. Samples for determination of percent organic matter are ground, passed through a 2 mm screen, and combusted. Reported total organic carbon may be underestimated if a portion of un-decomposed organic matter is excluded during screening. The following are general ratings for percent organic matter: 0.3% and below is “very low”; 0.4–2.2% is “low”; 2.3–3.7% is “medium”; 3.8–5.2% is “high”; and 5.3–15% is “very high”. Percent organic matter results are summarized in Table 15 by potential cover material type.

Table 15. Percent Organic Matter Analytical Summary

Potential Cover Material	Units	Count	Min.	Mean	Max.	Std. Dev.	Median	General Rating
Native Alluvium	%	5	1.0	1.3	1.6	0.3	1.4	Low
Oxide Tailings	%	3	1.3	1.7	2.4	0.6	1.5	low to medium
Sulfide Tailings	%	3	0.6	0.9	1.1	0.3	0.9	Low
W-3 WRA	%	3	1.1	1.4	1.6	0.3	1.4	Low
S-23 WRA	%	3	1.3	1.7	2.3	0.5	1.6	low to medium
South WRA	%	5	1.2	1.3	1.7	0.2	1.3	Low
Phase I/II HLP	%	2	1.8	n/a	2.0	n/a	n/a	Low
Phase III South HLP	%	2	2.2	n/a	2.4	n/a	n/a	low to medium
Phase III 4X HLP	%	2	1.3	n/a	1.5	n/a	n/a	Low
Phase IV Slot HLP	%	2	1.7	n/a	2.0	n/a	n/a	Low
Phase IV VLT HLP	%	2	1.5	n/a	1.9	n/a	n/a	Low

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

Soluble Salts
Soluble salts are measured from a saturated paste extract. The electrical conductivity of the soil extract gives an indication of the total concentration of soluble salts in the sample. High soluble salts can reduce water uptake by plants and restrict plant growth. Soluble salts results in Table 16 are reported in units of deciSiemens per meter (dS/m), which are equivalent to millimhos per centimeter. A soil is considered “saline” if this parameter is above 2.0 dS/m.

Table 16. Soluble Salts Analytical Summary

Potential Cover Material	Units	Count	Min.	Mean	Max.	Std. Dev.	Median	General Rating
Native Alluvium	dS/m	5	0.4	1.6	3.4	1.3	1.3	low to high
Oxide Tailings	dS/m	3	2.3	2.5	2.7	0.2	2.5	High
Sulfide Tailings	dS/m	3	1.4	2.4	3.2	0.9	2.5	medium to high
W-3 WRA	dS/m	3	1.1	1.6	1.9	0.4	1.7	medium
S-23 WRA	dS/m	3	1.2	3.1	4.6	1.7	3.5	medium to very high
South WRA	dS/m	5	0.3	0.5	0.7	0.1	0.5	very low
Phase I/II HLP	dS/m	2	3.2	n/a	3.9	n/a	n/a	High
Phase III South HLP	dS/m	2	4.8	n/a	5.1	n/a	n/a	very high
Phase III 4X HLP	dS/m	2	2.2	n/a	3.1	n/a	n/a	High
Phase IV Slot HLP	dS/m	2	2.7	n/a	5.2	n/a	n/a	high to very high
Phase IV VLT HLP	dS/m	2	2.4	n/a	5.2	n/a	n/a	high to very high

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

The following are general ratings for soluble salts: 0.3 dS/m and below = “very low”; 0.4–0.7 dS/m = “low”; 0.8–2.0 dS/m = “medium”; 2.1–4.0 dS/m = “high”; and 4.1–6.0 dS/m = “very high”. Soluble salts results are summarized in Table 16 by potential cover material type. Most potential cover material types were below the optimal soluble salts limit of 4.0 dS/m. Alluvial samples from the off-Site areas, W-3 WRA and the South WRA exhibited the lowest soluble salts with averages less than 1.6 dS/m. Samples from the Oxide Tailings (VLT materials), S-23 WRA and the Arimetco HLPs had the highest soluble salt contents.

Nitrogen, Phosphorus, and Potassium
Concentrations of Total Kjeldahl Nitrogen (TKN), the sum of organic nitrogen and ammonium nitrogen (NH_4-N), typically vary from relatively low concentrations of 100 mg/kg TKN to over 1,000 mg/kg. For example, in humid climates with higher percentages of organic matter, TKN concentrations can exceed 1% (10,000 mg/kg). Regardless of soil type, nitrogen is the most limiting nutrient for plant growth and TKN is an important parameter. Although TKN represents a “reservoir” of potentially available soil nitrogen, organic nitrogen must be converted to inorganic NH_4-N or nitrate nitrogen (NO_3-N) in the soil prior to being taken up by plants. Therefore, TKN provides the level of reserve nitrogen and NH_4-N and NO_3-N are the immediately available forms of nitrogen. Tables 17 and 18 indicate that both TKN and NO_3-N are present in the potential cover material samples, but at low concentrations.

One or both of two tests are commonly performed for phosphorous: 1) the P1 test (weak Bray) for acidic soils; and 2) the Olsen (sodium bicarbonate) test for basic soils. The Weak Bray test measures immediately available phosphorous and, for acidic soils, a phosphorous level above 30 mg/kg is desired for most plants. However, the Weak Bray extraction procedure is unreliable in calcareous soils with free lime, and the Olsen test is used to determine the amount of readily available phosphorous in slightly basic (pH 7.0-7.2) to highly basic (pH 7.3 and greater) soils. A phosphorous level above 15 mg/kg is typically desired. Phosphorous results are summarized in Table 19 for the potential cover material samples. The Olsen method was used for alluvial material sample locations with alkaline soil pH values. The Weak Bray method was used on the remaining potential cover materials which had acidic soil pH, and these materials generally had available phosphorous greater than the optimal 30 mg/kg level.

Table 17. Total Kjeldahl Nitrogen (TKN) Analytical Summary								
Potential Cover Material	**Units**	**Count**	**Min.**	**Mean**	**Max.**	**Std. Dev.**	**Median**	**General Rating**
Native Alluvium	mg/kg	5	155	191	246	35	183	low to medium
Oxide Tailings	mg/kg	3	37	55	78	21	51	Low
Sulfide Tailings	mg/kg	3	35	50	59	13	55	Low
W-3 WRA	mg/kg	3	56	72	96	21	63	Low
S-23 WRA	mg/kg	3	51	55	58	4	56	Low
South WRA	mg/kg	5	56	67	77	8	69	Low
Phase I/II HLP	mg/kg	5	72	119	250	75	92	low to medium
Phase III South HLP	mg/kg	4	58	127	250	86	99.5	low to medium
Phase III 4X HLP	mg/kg	4	53	161	390	155	100.5	low to medium
Phase IV Slot HLP	mg/kg	4	66	124	180	54	125.5	low to medium
Phase IV VLT HLP	mg/kg	4	39	89	130	40	94	low to medium

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

Table 18. Nitrate (NO_3-N) Analytical Summary								
Potential Cover Material	**Units**	**Count**	**Min.**	**Mean**	**Max.**	**Std. Dev.**	**Median**	**General Rating**
Native Alluvium	mg/kg	5	<0.4	1.62	3.3	1.59	1	very low
Oxide Tailings	mg/kg	3	0.6	0.93	1.2	0.31	1	very low
Sulfide Tailings	mg/kg	3	0.9	1.03	1.2	0.15	1	very low
W-3 WRA	mg/kg	3	0.8	1.4	2	0.6	1.4	very low
S-23 WRA	mg/kg	3	0.7	1.07	1.7	0.55	0.8	very low
South WRA	mg/kg	5	0.7	0.92	1.3	0.24	0.8	very low
Phase I/II HLP	mg/kg	2	0.9	n/a	1.5	n/a	n/a	very low
Phase III South HLP	mg/kg	2	1.6	n/a	1.9	n/a	n/a	very low
Phase III 4X HLP	mg/kg	2	0.6	n/a	0.7	n/a	n/a	very low
Phase IV Slot HLP	mg/kg	2	0.8	n/a	1	n/a	n/a	very low
Phase IV VLT HLP	mg/kg	2	0.5	n/a	0.7	n/a	n/a	very low

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

Table 19. Phosphorous Analytical Summary									
Potential Cover Material	**Units**	**Count**	**Min.**	**Mean**	**Max.**	**Std. Dev.**	**Median**	**Method(s)**	**General Rating**
Native Alluvium	mg/kg	5	6.2	7.7	11	2	6.6	Olsen	low to medium
Oxide Tailings	mg/kg	3	38	62	103	36	44.3	Weak Bray	high to very high
Sulfide Tailings	mg/kg	3	6.5	15	21	7	16.7	Weak Bray	very low to med
W-3 WRA	mg/kg	3	14	79	146	66	76.5	Weak Bray	low to very high
S-23 WRA	mg/kg	3	4.0	13	20	8	14.3	Weak Bray, Olsen	low to med
South WRA	mg/kg	5	2.3	7.5	16	5	6.7	Olsen	very low to high
Phase I/II HLP	mg/kg	2	68	n/a	113	n/a	n/a	Weak Bray	very high
Phase III South HLP	mg/kg	2	160	n/a	163	n/a	n/a	Weak Bray	very high
Phase III 4X HLP	mg/kg	2	69	n/a	91	n/a	n/a	Weak Bray	very high
Phase IV Slot HLP	mg/kg	2	81	n/a	81	n/a	n/a	Weak Bray	very high
Phase IV VLT HLP	mg/kg	2	81	n/a	87	n/a	n/a	Weak Bray	very high

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

Potassium results are presented as potassium concentration in soil (mg/kg) and percent potassium saturation. Generally, higher levels of potassium are needed in soils high in clay and organic matter than in soils which are sandy and low in organic matter. General ratings for potassium percent cation saturation are: 0.6% and below = “very low”; 0.7 to 2.0% = “low”; 2.1 to 5.0% = “medium”; 5.1 to 10% = “high”; and 11 to 15% = “very high”. Potassium percent saturation results, summarized in Table 20, indicate that the alluvial materials from the off-Site and South WRA sample locations exhibited the most optimal available potassium with a saturation range of 1.1 to 4.2% and that the other potential cover material types had considerably less percent potassium saturation.

Table 20. Potassium Analytical Summary

Potential Cover Material	Units	Count	Min.	Mean	Max.	Std. Dev.	Median	General Rating
Native Alluvium	% sat.	5	1.1	2.4	4.2	1	1.8	low to medium
Oxide Tailings	% sat.	3	0.2	0.3	0.4	0.1	0.2	very low
Sulfide Tailings	% sat.	3	0.1	0.4	0.9	0.4	0.2	very low to low
W-3 WRA	% sat.	3	0.1	0.3	0.7	0.3	0.1	very low to low
S-23 WRA	% sat.	3	0.1	0.4	0.8	0.4	0.2	very low to low
South WRA	% sat.	5	1.1	1.5	1.9	0.3	1.5	Low
Phase I/II HLP	% sat.	2	0.1	n/a	0.1	n/a	n/a	very low
Phase III South HLP	% sat.	2	0.1	n/a	0.1	n/a	n/a	very low
Phase III 4X HLP	% sat.	2	0.1	n/a	0.1	n/a	n/a	very low
Phase IV Slot HLP	% sat.	2	0.0	n/a	0.1	n/a	n/a	very low
Phase IV VLT HLP	% sat.	2	0.1	n/a	0.5	n/a	n/a	very low

Samples collected from W-3 WRA and S-23 WRA are fine-grained materials (no rock).

Plant Growth Parameter Summary

The suitability of potential cover materials to support volunteer or designed plant growth may be grouped by: 1) good potential for plant growth; 2) some potential to support plant growth with soil amendments; and 3) low potential to support plant growth with soil amendments. Based on the analytical results described above for plant growth parameters: 1) alluvial materials from the off-Site and South WRA would be anticipated to have good potential for plant growth; 2) finer grained materials from the S-23 WRA and from the Sulfide Tailings have some potential to support plant growth, with the addition of soil amendments; and 3) materials from the Oxide Tailings (VLT), the W-3 WRA and all Arimetco HLPs exhibit (very) low potential to support plant growth, even with soil amendments. These results are generally consistent with the geochemical results described above.

Geotechnical/Hydraulic Parameter Results

The ASWT geotechnical report and attachments (Attachment 7) describes the testing and results of potential cover materials, and ranks the samples based on geotechnical and hydraulic properties. Hydraulic properties summarized in Tables 21 through 23 were determined from test specimens remolded to dry densities and moisture contents expected to be representative of field conditions. As described in the ASWT geotechnical report (Attachment 7), volumetric moisture content values from laboratory SWCC test specimens were corrected for coarse particles that were not included in the test specimens, per the procedures described by Bouwer and Rice (1984).

Table 21 ranks the samples in order of decreasing plant-available soil moisture storage capacity. Bolded values shown in Table 21 indicate potential cover materials with a plant-available moisture storage capacity of approximately 0.9 inches per foot (0.07 inches per inch) or greater. The most favorable material types for soil moisture storage are alluvial materials (Native and South WRA alluvium) and the Sulfide Tailings. As indicated in the ASWT Report (Attachment 7), verification of this parameter, and other geotechnical properties, would need to be performed to assess cover hydraulic performance.

Typical ET covers have saturated hydraulic conductivity values of approximately 1 x 10^{-5} centimeters per second (cm/sec). Table 22 presents the bolded samples from Table 21 along with their saturated hydraulic conductivity values. Samples indicated by bold font in Table 22 exhibit saturated hydraulic conductivity values of approximately 1 x 10^{-5} cm/sec. Based on the information presented in Tables 21 and 22, alluvial materials are the most favorable potential cover material types.

Table 21. Plant-Available Storage Capacity

Sample	Plant-Available Storage Capacity	
	inches of water per foot of soil	inches of water per inch of soil
CM-BGS-05	**1.992**	**0.17**
CM-SUL-02	**1.548**	**0.13**
CM-SWR-05	**1.404**	**0.12**
CM-BGS-01	**1.368**	**0.11**
CM-SUL-01	**1.248**	**0.10**
CM-SUL-03	**1.224**	**0.10**
CM-BGS-04	**1.224**	**0.10**
CM-SWR-01	**1.020**	**0.09**
CM-BGS-02	**0.996**	**0.08**
CM-SWR-03	**0.984**	**0.08**
CM-SWR-04	**0.888**	**0.07**
CM-HLP-09	**0.888**	**0.07**
CM-S23-01	0.768	0.06
CM-VLT-09	0.768	0.06
CM-WR3-01	0.744	0.06
CM-BGS-03	0.744	0.06
CM-HLP-01	0.744	0.06
CM-S23-03	0.732	0.06
CM-VLT-05	0.720	0.06
CM-SWR-02	0.660	0.06
CM-WR3-03	0.648	0.05
CM-HLP-03	0.636	0.05
CM-VLT-06	0.636	0.05
CM-HLP-05	0.636	0.05
CM-HLP-07	0.624	0.05
CM-S23-02	0.480	0.04

Table 23 presents a statistical summary of the potential cover material types analyzed by ASWT. Values for unsaturated hydraulic conductivity are not presented because, as can be seen in Attachment L to the ASWT Report, unsaturated hydraulic conductivity varies by several orders of magnitude depending on the soil suction. Given that the suction in the cover will vary with time, and with depth in the cover profile, a single value would not represent field conditions in the field. Values for air-filled porosity are also not incorporated into Table 23. The term 'air-filled porosity' implies that a portion of the void space in the cover is filled with water and a portion of the void space is filled with air. This is indirectly an indication of the degree of saturation and/or volumetric moisture content. Because the saturation will vary with both time and with depth in the cover profile, the selection of a single value would be arbitrary and misleading.

Table 22. Saturated Hydraulic Conductivity Values	
Sample	**Saturated Hydraulic Conductivity, (cm/sec)**
CM-BGS-05	2.9×10^{-4}
CM-SUL-02	4.8×10^{-4}
CM-SWR-05	1.5×10^{-4}
CM-BGS-01	$\mathbf{2.3 \times 10^{-5}}$
CM-SUL-01	1.5×10^{-4}
CM-SUL-03	3.7×10^{-4}
CM-BGS-04	1.8×10^{-4}
CM-SWR-01	$\mathbf{4.4 \times 10^{-5}}$
CM-BGS-02	$\mathbf{1.4 \times 10^{-6}}$
CM-SWR-03	$\mathbf{1.3 \times 10^{-5}}$
CM-SWR-04	$\mathbf{4.0 \times 10^{-5}}$
CM-HLP-09	2.5×10^{-4}
CM-S23-01	3.4×10^{-4}
CM-VLT-09	3.0×10^{-4}

Interpretation of van Genuchten parameter statistics should be performed with caution. Because the four parameters are developed for a single material type or sample, the interpretation of the parameters individually may be misleading. For example, the maximum α and n values may come from different material types, that when combined, may result in a soil-water characteristic curve (SWCC) that is not representative of the overall cover profile. As indicated in Table 23, some of the SWCCs appear to be bi-modal. SWCCs generated using the van Genuchten function, with van Genuchten curve fit parameters, presented in Table 23 should be compared to the laboratory data to determine the appropriateness of the van Genuchten function to each material.

Table 23. Summary of Geotechnical Test Results

Analyses	Method	Off-Site Locations (west of site)	On-Site Locations					
		Native Alluvium	Oxide Tailings (VLT)	Sulfide Tailings	W-3 Waste Rock Area	S-23 Waste Rock Area	South Waste Rock Area	HLPs
Saturated hydraulic conductivity (cm/s)	ASTM D5084							
Sample size (n)		5	3	3	2	3	5	5
Minimum		1.43E-06	2.96E-04	1.54E-04	2.32E-04	1.71E-04	1.30E-05	1.92E-04
Maximum		4.16E-04	4.03E-04	4.77E-04	4.32E-04	3.39E-04	1.53E-04	6.63E-04
Mean		1.70E-04	3.33E-04	3.32E-04	3.32E-04	2.29E-04	5.30E-05	4.00E-04
Median		1.18E-04	3.00E-04	3.65E-04	3.32E-04	1.77E-04	3.98E-05	2.90E-04
Standard deviation								
Total porosity	90% of Max DD							
Sample size (n)		5	3	3	2	3	5	5
Minimum		0.34	0.30	0.47	0.28	0.28	0.23	0.30
Maximum		0.38	0.32	0.49	0.31	0.29	0.37	0.32
Mean		0.36	0.31	0.48	0.30	0.28	0.32	0.31
Median		0.37	0.32	0.48	0.30	0.28	0.32	0.32
Standard deviation								
Soil-Water Characteristic Curve Data:	ASTM D6836							
Volumetric water content (θ)								
Volumetric water content at saturation (θs)								
Sample size (n)		5	3	3	2	3	5	5
Minimum		0.29	0.25	0.42	0.23	0.23	0.18	0.25
Maximum		0.33	0.27	0.44	0.26	0.24	0.32	0.27
Mean		0.312	0.263333	0.43	0.245	0.233333	0.266	0.264
Median		0.32	0.27	0.43	0.245	0.23	0.27	0.27

Table 23. Summary of Geotechnical Test Results

Analyses	Method	Off-Site Locations (west of site)	On-Site Locations					
		Native Alluvium	Oxide Tailings (VLT)	Sulfide Tailings	W-3 Waste Rock Area	S-23 Waste Rock Area	South Waste Rock Area	HLPs
Irreducible minimum water content (θr)								
Sample size (n)		5	3	3	2	3	5	5
Minimum		0	0	0	0	0	0	0
Maximum		0.08602	0	0.00291	0	0	0.04689	0
Mean		0.020284	0	0.00097	0	0	0.009378	0
Median		0	0	0	0	0	0	0
Van Genuchten *α*								
Sample size (n)		5	3	3	2	3	5	5
Minimum		0.00659	0.15865	0.03583	0.18074	0.09522	0.001125	0.08184
Maximum		0.9385	0.51185	0.08827	0.18078	1.83808	0.68487	0.89065
Mean		0.200592	0.28433	0.066163	0.18076	0.68503	0.169993	0.388874
Median		0.01999	0.18249	0.07439	0.18076	0.12179	0.04771	0.33579
Van Genuchten *n*								
Sample size (n)		5	3	3	2	3	5	5
Minimum		1.14453	1.16579	1.28463	1.15828	1.14662	1.1513	1.11005
Maximum		1.55112	1.1903	1.35216	1.20983	1.24042	1.74851	1.17655
Mean		1.310988	1.180937	1.324343	1.184055	1.19445	1.349656	1.14855
Median		1.29266	1.18672	1.33624	1.84055	1.19631	1.23574	1.14921

vanGenuchten m set as m = 1-(1/n)

Data Quality Assurance/Quality Control

In addition to the field decontamination issues discussed above and provided in Attachment 2, typical data verification and validation was performed according to the QAPP – Revision 5 (ESI and Brown and Caldwell, 2009a). The following sections provide a quality assurance/data control (QA/QC) summary for total metals, radiochemicals, and MWMP leachate results.

QA/QC Summary for Total Metals and Radiochemicals
A total of 36 primary samples were collected in September/October 2010 for analysis of total metals and radiochemicals (24 backhoe/auger samples and 12 rock grab samples). A total of three field duplicate samples were collected that are associated with the 24 backhoe/auger samples. Level IV data validation was performed on Sample Delivery Groups (SDGs) J0J190512 and ITK0252, which are provided in Attachment 3. Tables 24 and 25 provide a summary of the number of samples analyzed by each method and the number of results that were qualified for each method. Samples were analyzed for the list of parameters indicated in Table 1, with the exception of the following (per the Revised Work Plan): ten Oxide Tailings (VLT) samples were analyzed only for uranium, thorium, radium-226, and radium-228.

Backhoe/auger sample results met the data quality objectives, and all data are considered usable for the stated objectives of the Revised Work Plan. Completeness goals were achieved for every method and analyte. The primary issues that resulted in the qualification of results are:

- Laboratory replicate imprecision for radium-226;
- High matrix spike recoveries for ICP metals; and
- High matrix spike recoveries, field duplicate imprecision, and blank contamination for ICP/MS metals.

Rock grab sample results met the data quality objectives, and all data are considered usable for the stated objectives of the Revised Work Plan. Completeness goals were achieved for every method and analyte. The primary issues that resulted in data qualification are:

- Laboratory replicate imprecision for radium-226;
- High matrix spike recoveries for ICP metals; and
- High and low matrix spike recoveries for ICP/MS metals.

Results qualified as estimated should be used with caution. Tables 24 and 25 for backhoe/auger and rock grab samples, respectively, provide a summary of the number of samples analyzed by each method and the number of results that were qualified for each method.

QA/QC Summary for MWMP Leachate Metals and Radiochemicals
A total of 41 samples (12 rock grab samples and 29 backhoe samples) were subject to the MWMP. Level IV data validation was performed on SDGs J0K010406 and ITJ2624, which are provided in Attachment 4. Table 26 provides a summary of the number of samples analyzed by each method and the number of results that were qualified for each method. All MWMP leachate samples were analyzed for the full list of parameters in Table 26 with the following exception: sample CM-S23-01-MWMP was not analyzed for thorium due to a lab error which left insufficient sample quantity for thorium analysis. Overall, the MWMP leachate data met the data quality objectives, and all data is considered usable for the stated objectives of the Revised Work Plan. Completeness goals were achieved for every method and analyte. The primary issues that resulted in data qualification of results were:

- Field blank contamination for thorium;
- High matrix spike recoveries for radium-226;
- High matrix spike recoveries and blank contamination for ICP metals; and
- Serial dilution problems and blank contamination for ICP/MS metals.

Table 24. Quality Control Summary for Total Metals and Radiochemicals (Backhoe/Auger Samples)

Method	Parameter	Samples Analyzed (N+FD)	Analytes per sample	Number of results: Total	Rejected	Estimated due to QC deficiencies	Estimated due to >MDL but <PQL	Completeness: Percent usable	Percent quantitative*
E1631	Mercury	14+3	1	17	0	0	0	100%	100%
E901.1	Radium-226 and-228	24+3	2	54	0	12	3	100%	77.7%
SW6010B	ICP Metals	14+3	7	119	0	8	10	100%	93.3%
SW6020	ICPMS Metals	14+3	17	289	0	31	53	100%	89.3%
SW6020	Thorium and Uranium	24+3	2	54	0	2	0	100%	96.3%

* Note: Estimations due solely to results <PQL do not affect the calculated completeness
Calculations do not include any required field or laboratory QC samples, except field duplicates.
N = normal environmental samples FD = field duplicate samples

Table 25. Quality Control Summary for Total Metals and Radiochemicals (Rock Samples)

Method	Parameter	Samples Analyzed (N+FD)	Analytes per sample	Number of results: Total	Rejected	Estimated due to QC deficiencies	Estimated due to >MDL but <PQL	Completeness: Percent usable	Percent quantitative*
E1631E	Mercury	12+0	1	12	0	0	0	100%	100%
E901.1	Radium-226 & -228	12+0	2	24	0	1	9	100%	95.8%
SW6010B	ICP Metals	12+0	7	84	0	1	8	100%	98.8%
SW6020	ICP/MS Metals	12+0	19	228	0	83	46	100%	63.6%

* Note: Estimations due solely to results <PQL do not affect the calculated completeness
Calculations do not include any required field or laboratory QC samples, except field duplicates.
N = normal environmental samples FD = field duplicate samples

Table 26. Quality Control Summary for MWMP Leachate

Method	Parameter	Samples Analyzed (N+FD)	Analytes per sample	Number of results: Total	Rejected	Estimated due to QC deficiencies	Estimated due to >MDL but <PQL	Completeness: Percent usable	Percent quantitative*
E200.1	Thorium	40+0	1	40	0	2	14	100%	95%
E245.1	Mercury	41+0	1	41	0	0	12	100%	100%
E903.0	Radium-226	41+0	1	41	0	24	20	100%	42%
E904.0	Radium-228	41+0	1	41	0	0	10	100%	100%
SW6010B	ICP Metals	41+0	7	287	0	63	7	100%	78%
SW6020	ICP/MS Metals	41+0	18	738	0	37	156	100%	95%

* Note: Estimations due solely to results <PQL do not affect the calculated completeness
Calculations do not include any required field or laboratory QC samples, except field duplicates.
N = normal environmental samples FD = field duplicate samples

Summary of Findings

As discussed in previous sections of this Potential Cover Materials DSR, a variety of material types were evaluated for geochemical, acid generating potential, plant growth and geotechnical characteristics. Based on these results, some of the evaluated materials have been determined to be quite favorable for use as cover materials based on certain characteristics, while other characteristics are not as favorable. For example, the information presented above indicates that: 1) spent ore materials cannot support the degree of volunteer or designed vegetation observed at the South WRA: and 2) alluvial fan materials within the South WRA and in off-Site undisturbed areas will support volunteer or designed plant growth of native species. Spent ore materials that cannot support the degree of volunteer or designed vegetation observed at the South WRA should not be subject to further plant growth analyses. A summary of the material types and favorability for their use as cover materials, based on select characteristics, is presented in Table 27.

Table 27. Summary of Potential Cover Materials Characteristics

Characteristic Category	Native alluvium	South WRA (soil)	W-3 WRA	S-23 WRA	Oxide Tailings	Sulfide Tailings	Arimetco HLPs	Coarse rock		
								South WRA	W-3 WRA	S-23 WRA
Metals & radiochemical mean/maximum values (compared to Native Alluvium)	●	●	○	○	○	◉	○	○	○	○
MWMP leachate concentrations less than drinking water MCLs	◉	◉	○	○	○	○	○	◉	○	○
Acid generating potential	●	●	◉	◉	◉	◉	○	◉	◉	◉
Potential to support plant growth	●	●	○	◉	○	◉	○			
Plant-available moisture storage capacity	●	●	○	○	○	●	○			
Saturated hydraulic conductivity	●	●	○	○	○	○	○			

● Most favorable for use as capping material relative to other cover material types

◉ Moderately favorable

○ Least favorable

Materials have been identified as “most favorable”, “moderately favorable”, and “least favorable” based on the material characteristics described above and summarized below. Some of these determinations are based on a comparison between on-Site materials and Native Alluvium (i.e., background soil samples). The cover design that is selected and implemented may implement use of one or more of these materials into a cover system rather than just the use of one material. As part of an integrated cover design, less favorable spent ore materials (e.g., Arimetco HLPs and oxide tailings) can be used as part of a final cover design (i.e., as interim covers) because they would capped by favorable materials such as South WRA or Native Alluvium with suitable plant growth and hydraulic properties.

Total Metals and Radiochemicals
Potential cover materials were evaluated on the basis of total metal and radiochemical results in comparison to Site-specific BCLs:

- Most favorable: (near) equivalent to BCL.
- Moderately favorable: some parameters detected at levels higher than the BCL.
- Least favorable: many parameters greater than BCLs (some metals significantly greater).

MWMP Soluble Metals
MWMP leachate results for metals and radiochemicals were compared to EPA drinking water standard to determine if any of the materials produces a leachate that exceeds MCL:

- Most favorable: no parameters exceed MCLs
- Moderately favorable: up to 6 parameters exceed MCLs
- Least favorable: greater than 6 parameters exceed MCLs

Acid Generating Potential
Materials were evaluated based on their NNP and NPR values:

- Most favorable: NNP > 20
- Moderately favorable: NNP = -20 to +20
- Least favorable: NNP < -20

- Most favorable: NPR > 3
- Moderately favorable: NPR = 1-3
- Least favorable: NPR < 1

Potential to Support Plant Growth
As described above, several parameters can impact plant growth potential (e.g., pH, cations, CEC, metals and nutrients). Although soil pH was selected for use in Table 27, the other important plant growth parameters listed above would result in the same conclusion based on soil pH, as presented below:

- Most favorable: pH is neutral (7 to 9 pH)
- Moderately favorable: pH is slightly acidic (5 to 7 pH; some amendments required)
- Least favorable: pH is acidic (<5 pH; cannot support plant growth with significant amendments

Plant Available Water Storage Capacity
As measured in inches of soil water storage capacity per foot of soil column:

- Most favorable: storage capacity >1.0 inches of water per foot of soil
- Moderately favorable: storage capacity = 0.8 to 1.0 inches per foot
- Least favorable: storage capacity <0.8 inches per foot

Saturated Hydraulic Conductivity
Based on the saturated hydraulic conductivity results for remolded soil samples (measured in cm/sec movement of water through the soil column):

- Favorable: approximately 1.0×10^{-5} cm/sec or less
- Less favorable: greater than approximately 1.0×10^{-5} cm/sec

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List of Acronyms and Abbreviations

ABA	Acid-Base Accounting
AGP	Acid Generation Potential
AOC	Administrative Order on Consent
ARC	Atlantic Richfield Company
ASTM	American Society of Testing and Materials
ASWT	Applied Soil Water Technologies
BCL	Background Concentration Limit
CEC	Cation Exchange Capacity
CERCLA	Comprehensive Environmental, Response, Compensation, and Liability Act
DSR	Data Summary Report
EPA	U.S. Environmental Protection Agency
ESI	Environmental Standards Inc.
ET	Evapotranspiration
FD	Field Duplicate
HASP	Health and Safety Plan
HLP	Heap Leach Pad
ICP/MS	Inductively Coupled Plasma/Mass Spectrometry
MCL	Maximum Contaminant Level
MWMP	Meteoric Water Mobility Procedure
NAG	Net Acid Generation
NAPT	North American Proficiency Testing Program
NDEP	Nevada Division of Environmental Protection
NNP	Net Neutralization Potential
NP	Neutralization Potential
NPK	Nitrogen, Phosphorus, and Potassium
NPR	Neutralization Potential Ratio
PAG	Potentially Acid Generating
OU	Operable Unit
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RI/FS	Remedial Investigation/ Feasibility Study
RSL	Regional Screening Level
SAR	Sodium Adsorption Ratio
SDG	Sample Delivery Group
SEM	Sierra Environmental Monitoring
Site	Yerington Mine Site
SLERA	Screening-Level Ecological Risk Assessment
SOP	Standard Operating Procedure
SOW	Scope of Work
SWCC	Soil Water Characteristic Curve
SX/EW	Solvent Extraction/ Electro-Winning
TENORM	Technologically Enhanced Naturally-Occurring Radioactive Materials
TKN	Total Kjeldahl Nitrogen
TTAL	Treatment Technique Action Level
VLT	Vat Leach Tailings
WRA	Waste Rock Area
XRF	X-ray Fluorescence

bgs	below ground surface
$CaCO_3$	calcium carbonate
cm/sec	centimeters per second
dS/m	deciSiemens per meter
meq/g	milliequivalents per gram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
pCi/g	picocuries per gram
$tCaCO_3/kt$	tons of calcium carbonate per kiloton

If you have any questions or comments regarding this Potential Cover Materials DSR, please contact me at 714-228-6774 or via e-mail at Jack.Oman@bp.com.

Sincerely,

Jack Oman
Project Manager

Attachments